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LITIGATION TECHNICAL SUPPORT AND SERVICES

Rocky Mountain Arsenal

North Boundary System Component
Response Action Assessment

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Final Technical Plan
(Version 3.1)
February 1988
Contract Number DAAK11-84-D-0016
Task Number 36

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PREPARED BY

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.
Harding Lawson Associates

PREPARED FOR

Office of Program Manager
Rocky Mountain Arsenal Contamination Cleanup

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THE PURPOSE OF TASK 36 IS TO COLLECT, ASSEMBLE, AND EVALUATE EXISTING AND NEW GEOTECHNICAL, HYDROLOGIC, AND WATER QUALITY DATA TO 1) EXAMINE THE SYSTEM COMPONENTS OF THE NORTH BOUNDARY CONTAINMENT SYSTEM (NBCS) AND 2) EVALUATE RESPONSE ACTIONS WHICH SHOULD INCREASE SYSTEM EFFICIENCY. THIS TASK WILL FURTHER CHARACTERIZE THE GEOLOGIC REGIME IN THE VICINITY OF THE NBCS. A HYDROLOGIC EVALUATION WILL ALSO BE PERFORMED USING PRIMARILY WATER LEVEL AND QUALITY DATA. THE SCOPE OF WORK INCLUDES DEVELOPMENT, INSTALLATION, AND SAMPLING OF NEW MONITORING WELLS PLUS AN EVALUATION OF THE PHYSICAL CONDITION, INTEGRITY, AND HYDROLOGIC PROPERTIES OF THE BARRIER.

SECTIONS OF THIS PLAN DETAIL PROCEDURES TO BE USED IN THE FOLLOWING PROGRAMS:

1. GEOTECHNICAL INVESTIGATION
2. CHEMICAL ANALYSIS
3. QUALITY ASSURANCE
4. SAFETY

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TABLE OF CONTENTS
(Page 1 of 3)

TABLE OF CONTENTS
(Continued, Page 2 of 3)

TABLE OF CONTENTS
(Continued, Page 3 of 3)

LIST OF FIGURES
(Page 1 of 2)

LIST OF FIGURES
(Continued, Page 2 of 2)

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS
(Page 1 of 2)

AR	Army Regulation
CA	Contamination Assessment
CDH	Colorado Department of Health
cm	centimeters
COE	U.S. Army Corps of Engineers
cpt	cone penetration test
CSEO	Colorado State Engineers Office
CSEO	Colorado State Engineers Office
DARCOM	U.S. Army Material Development and Readiness Command
DA-PAM	Department of Army Pamphlet
DBCP	dibromochloropropane
DCPD	dicyclopentadiene
DIMP	diisopropylmethylphosphonate
DMMP	dimethylmethylphosphonate
ESE	Environmental Science and Engineering, Inc.
ft	feet
gpd/ft	gallons per day/foot
gpm	gallons/minute
MIBK	methylisobutylketone
MOA	Memorandum of Agreement
NBCS	North Boundary Containment System
OSHA	Occupational Safety and Health Administration
PMO-RMA	U.S. Army Program Manager's Office-Rocky Mountain Arsenal Contamination Cleanup
ppm	parts per million
QA	Quality Assurance
QC	Quality Control
RIC	Rocky Mountain Arsenal Resource Information Center
RMA	Rocky Mountain Arsenal
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USEPA	U.S. Environmental Protection Agency
WES	U.S. Army Engineer Waterways Experiment Station

EXECUTIVE SUMMARY

The North Boundary Containment System (NBCS) was designed to intercept contaminated and potentially contaminated ground water which flow through areas within Rocky Mountain Arsenal (RMA) toward the northern site boundary. The system was designed to treat and recharge this extracted ground water. A pilot containment system was constructed in 1978 and consisted of a 1,500-ft long soil-bentonite barrier, 6 dewatering wells, and 12 recharge wells. The system was expanded in 1981 to the present configuration which includes a 6,740-ft long soil-bentonite barrier, 54 dewatering wells, and 38 recharge wells.

The purpose of this task is to collect, assemble, and evaluate existing and new geotechnical, hydrologic, and water quality data to examine the system components of the NBCS and to evaluate response actions which should increase system efficiency. To accomplish these objectives, this task will further characterize the geologic regime in the vicinity of the NBCS utilizing data from previous investigations and additional data to be collected as part of this task. Where historical data is lacking, additional soil borings will be constructed and soil/bedrock samples collected. Particular attention will be directed to the areal extent and position of Denver sand units.

In addition to the geologic characterization, a hydrologic evaluation will be performed using primarily water level and quality data. Much of this data is being collected as part of the Regional Water Quality/Water Quantity Survey (Tasks 4 and 44) and the Boundary Systems Monitoring (Task 25) task. To complement the information available from these tasks and fill data deficiencies, the Task 36 scope-of-work includes installation, development, and sampling of new ground water monitoring wells in selected locations. As these new wells are completed and developed, they will be sampled for water quality parameters to aid in the identification of other locations for which monitoring wells may provide valuable information and will be sampled in coordination with Task 25 and 44 sampling events to provide an integrated data set.

Using the data described above, an assessment of the hydrologic conditions in the vicinity of the NBCS will be performed. This will include an assessment of both dewatering and recharge components of the NBCS as well as the hydrologic relationship between saturated portions of the alluvium and the Denver Formation.

To complete the assessment of the NBCS, the Task 36 Scope-of-Work will include an evaluation of the physical condition, integrity, and hydrologic properties of the soil-bentonite barrier. Samples of the barrier will be collected and subjected to both physical and hydrologic testing. This data in conjunction with results of the geologic and hydrologic assessment should allow evaluations of the effectiveness of the barrier.

Upon completion of data assessment, candidate response actions which may enhance system performance will be developed and evaluated. These actions may include physical modification to the NBCS and/or modifications to the NBCS operational procedures. The preferred response actions will be recommended for implementation and categorized as to whether they should be considered as interim of long-term actions.

1.0 INTRODUCTION

The Rocky Mountain Arsenal (RMA) occupies 27 square miles in southern Adams County, Colorado (Figure 1.0-1). It lies within the Denver metropolitan area just north of the City of Denver and just east of Commerce City, Colorado. Since startup in 1942, RMA has been a site for the manufacture and demilitarization of chemical, incendiary munitions, and the manufacture of industrial chemicals, primarily pesticides and herbicides. A detailed account of disposal practices associated with these operations and an overview of resulting soil and water contamination are presented in the Task 1 Technical Plan (ESE, 1985, RIC#85127R07).

The disposal practices of the Army and leaseholders took place over a period of approximately 40 years and led to the widespread introduction into the ground water of a host of organic and inorganic contaminants; most notably, chloride, fluoride, diisopropylmethyl phosphonate (DIMP), dicyclopentadiene (DCPD), dibromochloropropane (DBCP), organosulfur compounds, organochlorine pesticides, volatile aromatic compounds, and volatile organohalogen compounds. Ground water monitoring programs conducted since the mid-1970's have detected some or all of these compounds near or outside the boundaries of RMA.

To curtail migration of contaminants from the North Boundary of RMA, a ground water containment and treatment system was constructed near the boundary in two phases, a pilot system in 1978 and an expansion in 1981. The four major components of the system that will be examined in detail are the dewatering/recharge system; the soil-bentonite barrier; the extent and configuration of Denver sands units near the North Boundary; and the carbon adsorption treatment system. The objectives of Task 36 are to assess the integrity of the various components of this contamination control system, investigate the hydrogeologic regime and its response to the operation of the system, and propose operational and/or design modifications to response to any problems that might exist.

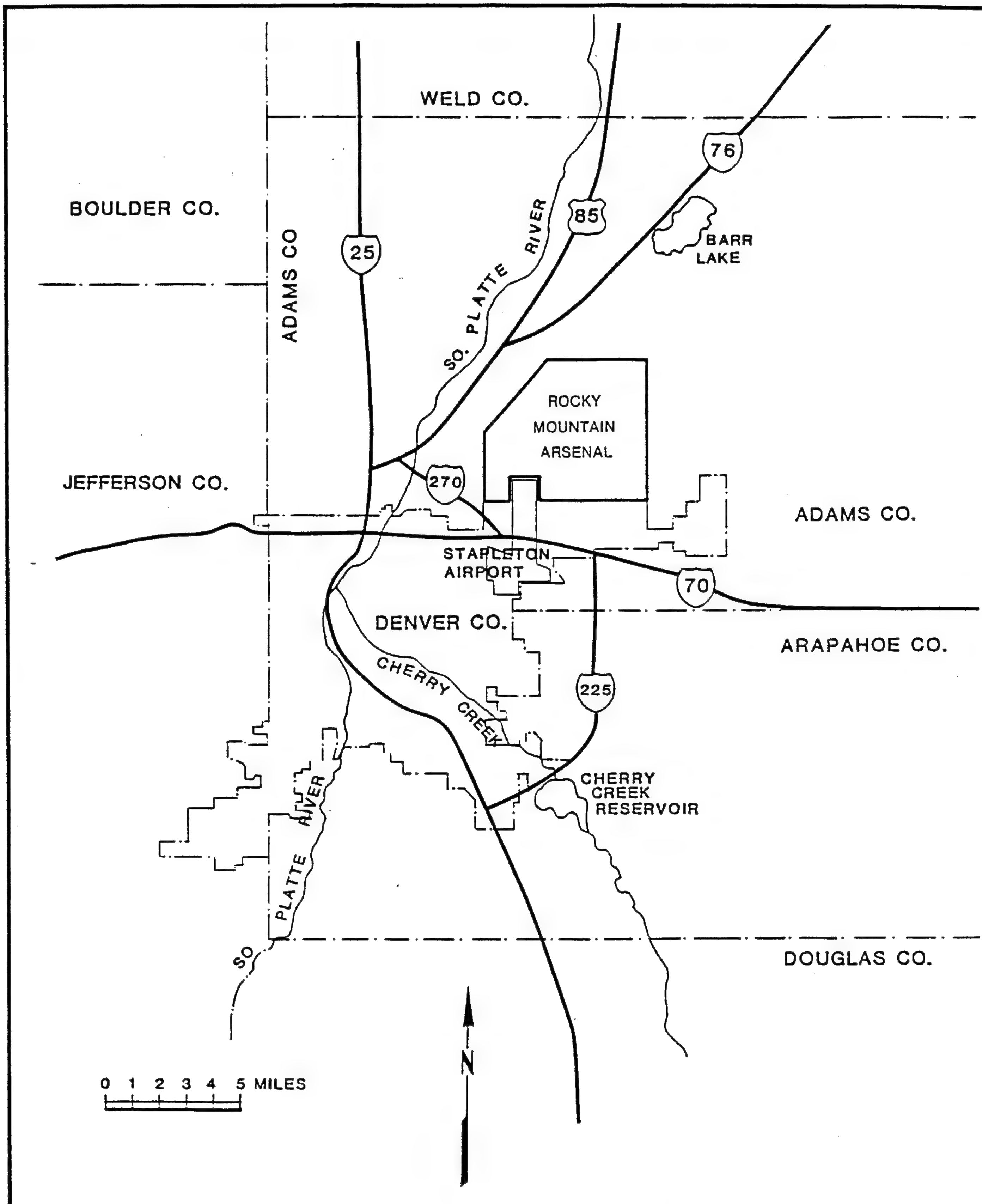

Figure 1.0-1
LOCATION MAP OF
ROCKY MOUNTAIN ARSENAL

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

1.1 STATEMENT OF THE PROBLEM

A comprehensive study conducted in fiscal year 1984 and detailed in the North Boundary Containment/Treatment System Performance Report by Thompson, et al. (1985, RIC#86078R01) has outlined the success of the system in:

- o Acting as a barrier to the majority of the contaminated alluvial ground water flow in the area;
- o Effectively removing the organic contaminants from the extracted ground water; and
- o In general reducing contaminant levels downgradient.

That study also identified several problems which need to be addressed:

- o The development of a high [up to 10 feet (ft)] hydraulic head differential across the soil-bentonite wall from the upgradient to the downgradient side;
- o Significant concentrations of some contaminants are still detected north of the system in the offpost area;
- o The inability of the recharge wells to effectively handle all of the treated effluent;
- o Some low levels of contamination have been detected in upper Denver Formation sandstone units in contact with the alluvium north of the barrier; and
- o An area of potential flow between a Denver Formation sandstone and the alluvial aquifer has been identified below the pilot barrier portion of the soil-bentonite barrier.

This study will focus on addressing these problems in detail and identifying modifications that will improve the system's effectiveness.

1.2 NORTH BOUNDARY CONTAINMENT SYSTEM DESCRIPTION

The North Boundary Containment System (NBCS) is located about 250 ft south of the north boundary of RMA in Sections 23 and 24 (Figure 1.2-1). It consists of a 6,740-ft-long soil-bentonite barrier, a series of 54 ground water withdrawal wells, a carbon-adsorption type water treatment plant, and a line of 38 recharge wells.

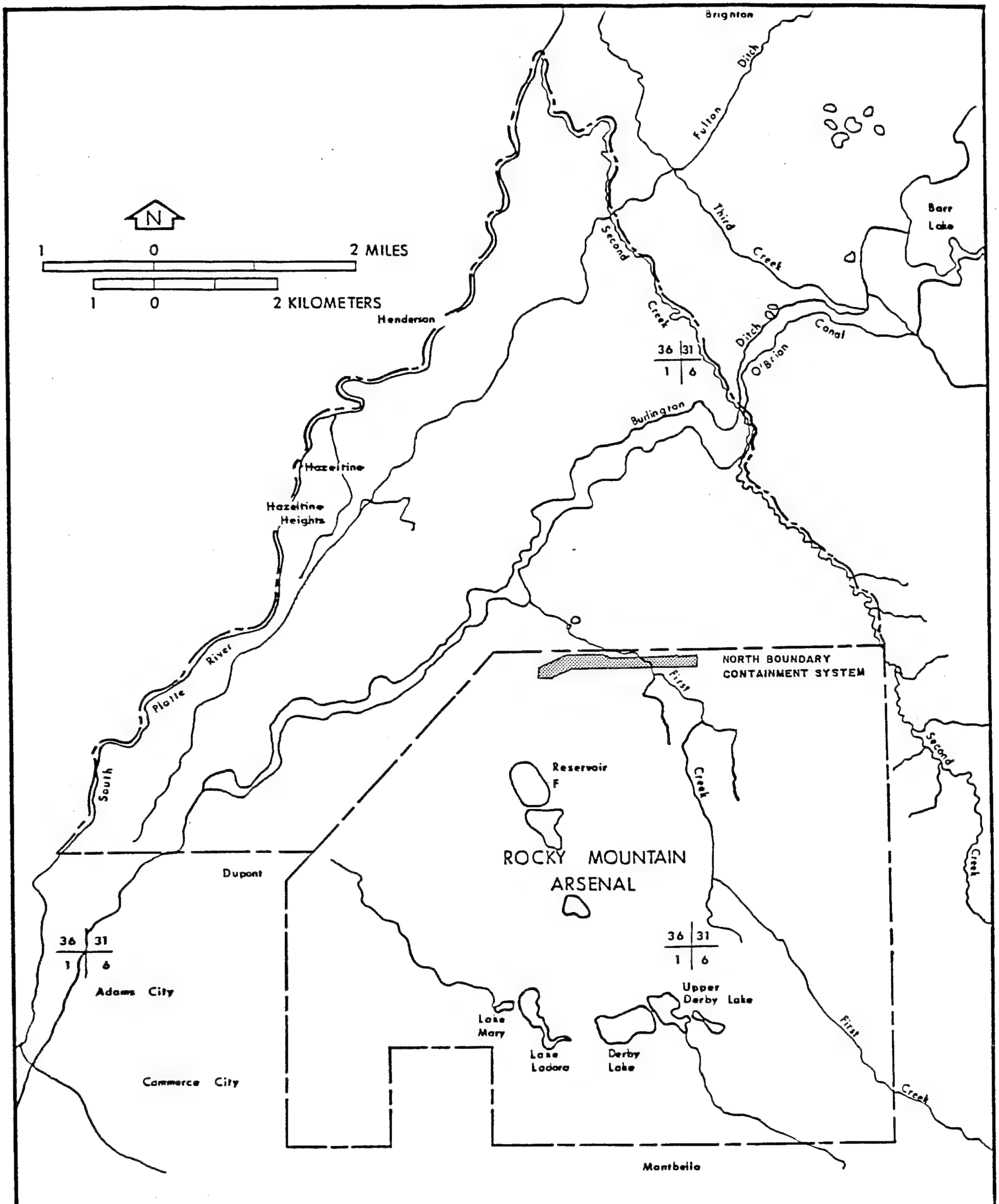

Figure 1.2-1
NORTH BOUNDARY CONTAINMENT SYSTEM LOCATION MAP

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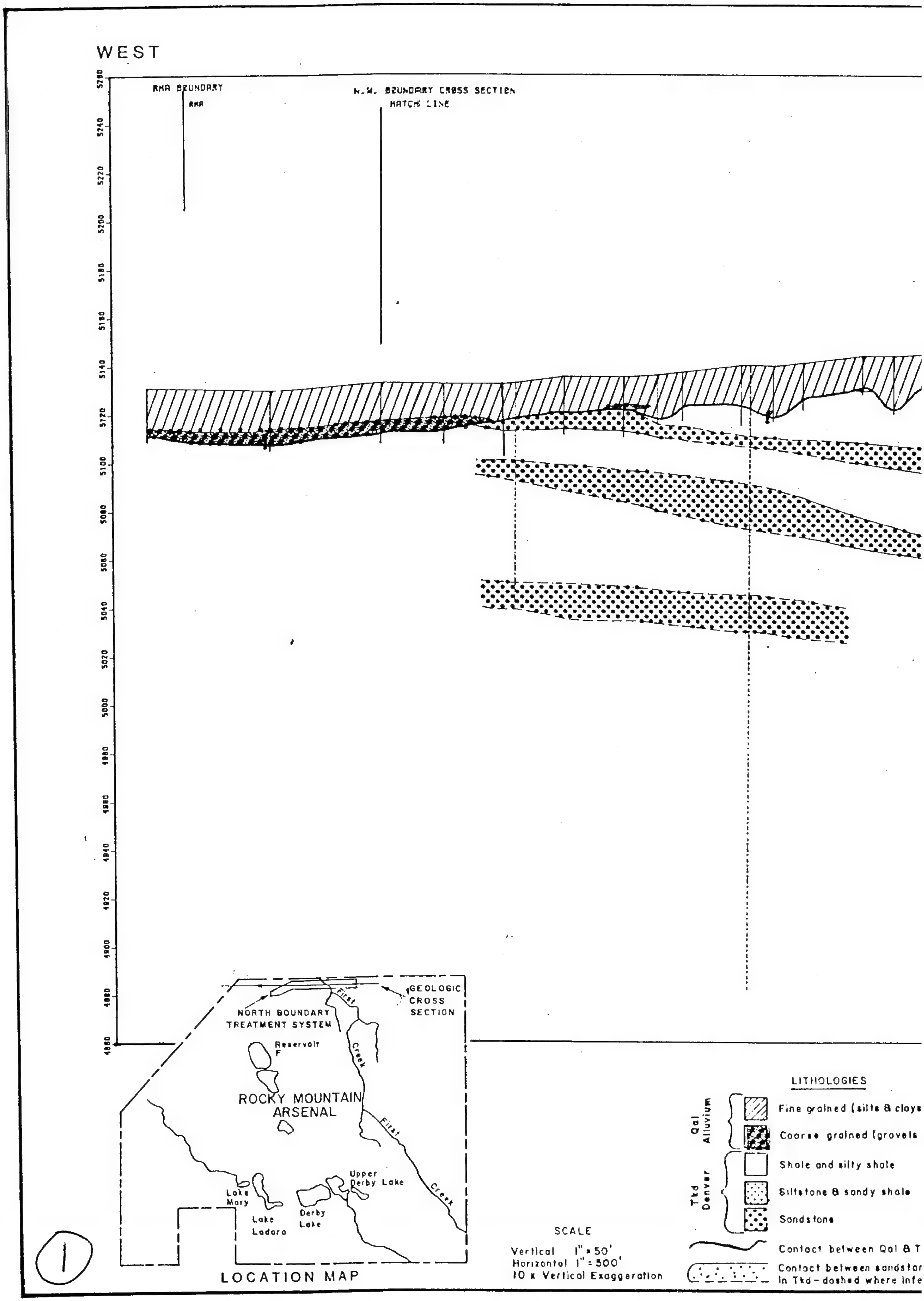
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

1.2.1 GEOLOGY

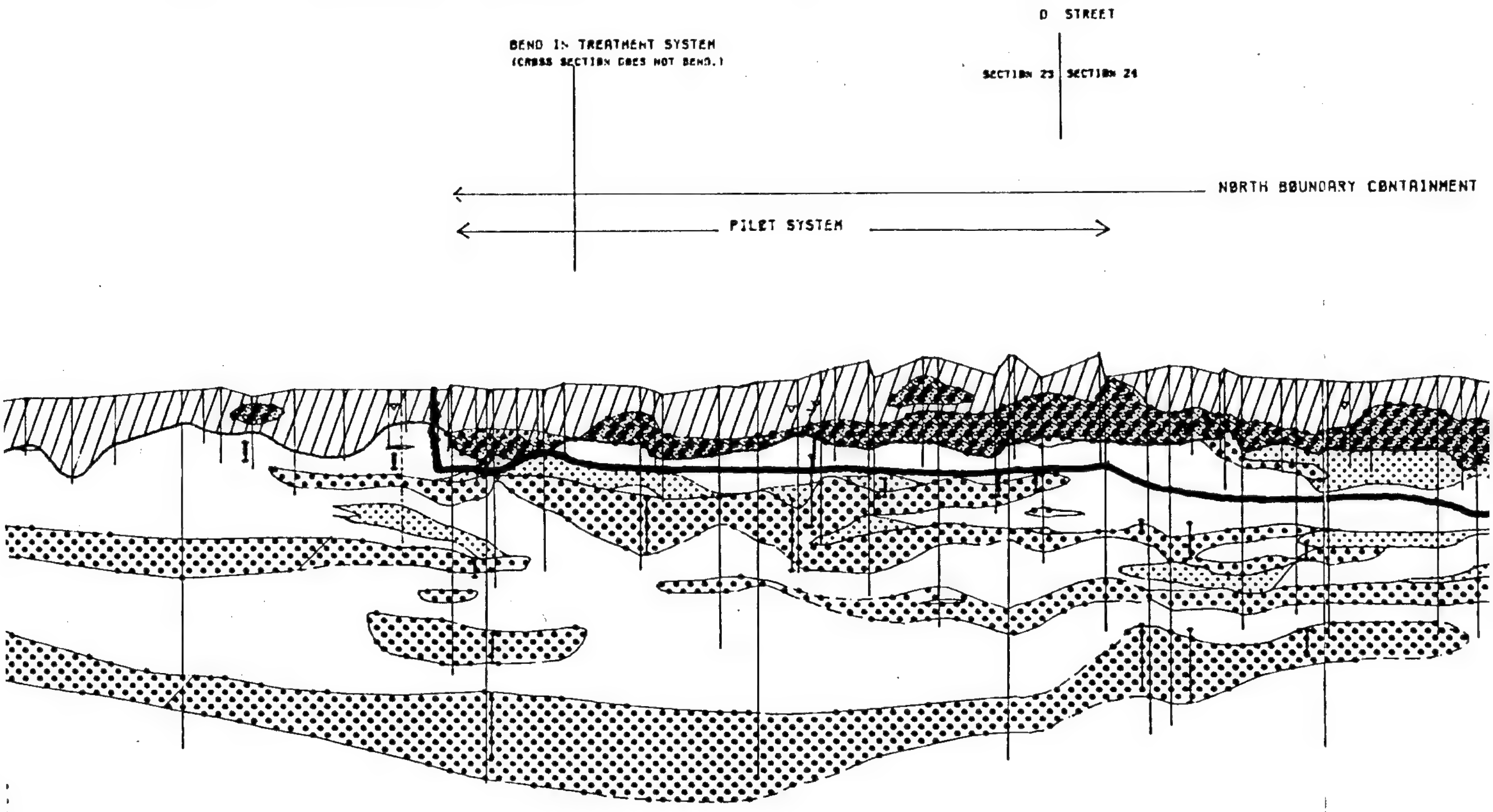
Along the North Boundary the geology consists of two major stratigraphic units; the Quaternary alluvium and the Cretaceous-Tertiary Denver Formation. The system extends across a north- to northeast-trending alluvial valley that is incised into the underlying Denver Formation (Figure 1.2-2). The valley is filled with unconsolidated sediments of Holocene to Pleistocene Age ranging up to 30 ft in thickness and consisting of lower units of sand and gravel averaging about 12-ft thick and upper units of silts and clays averaging about 15-ft thick (Figures 1.2-2 and 1.2-3).

The unconsolidated sediments are underlain by the Denver Formation which consists of 210 to 370 ft of olive, bluish gray, green gray, and brown clay, shale, and siltstone interbedded with poorly sorted, weakly lithified tan to brown, fine to medium grained, lenticular sandstone and conglomerate. Lignite beds and carbonaceous shales are common, and to a lesser degree are volcanic fragments, and tuffaceous materials. Minor beds of bentonite may also be present. The predominant olive green-gray colors resulting from erosion and weathering of andesitic and basaltic lavas help distinguish the formation from the underlying lighter colored Arapahoe Formation. The Denver Formation in the area of the NBCS consists of approximately 30 to 40 percent sand and to 60 to 70 percent silt and shale.

Significant water bearing zones in the formation are generally restricted to sandstone lithologies which are lenticular in nature and irregularly distributed within thick clay-shale sequences. They are discontinuous and therefore difficult to trace, and are poorly defined where sandstones grade into encompassing clay and shale. In the area of the NBCS, sand comprises lenticular to tabular horizons up to 20-ft thick and more than 500-ft long whose three-dimensional configurations and connections are complex and poorly understood. It appears that sandstone horizons which are present below the treatment system, project updip to the surface and subcrop to the north of 96th Avenue (Figure 1.2-3). A detailed study of the Denver Sands will be included in the Task 36 System Assessment (Section 8.0).



WEST
RMA BOUNDARY
RMA
N.W. BOUNDARY CROSS SECTION
MATCH LINE
GEOLOGIC CROSS SECTION
NORTH BOUNDARY TREATMENT SYSTEM
First Creek
Reservoir F
ROCKY MOUNTAIN ARSENAL
First Creek
Upper Derby Lake
Lake Mary
Lake Ladora
Derby Lake
LOCATION MAP
SCALE
Vertical 1" = 50'
Horizontal 1" = 500'
10 x Vertical Exaggeration
LITHOLOGIES
Qal Alluvium
Fine grained (silts & clays
Coarse grained (gravels
Tkd Denver
Shale and silty shale
Siltstone & sandy shale
Sandstone
Contact between Qal & T
Contact between sandston
In Tkd – dashed where infe
1



EXPLANATION

ЗIES

I (silts & clays)

ined (gravels & sands)

ilty shale

sandy shale

lween Qal & Tkd

ween sandstone & shale
ıed where inferred

SYMBOLS

Bore (dashed where projected > 100 ft. from foregound)

Water level (3/86)

Screened interval

Outline of slurry wall

2

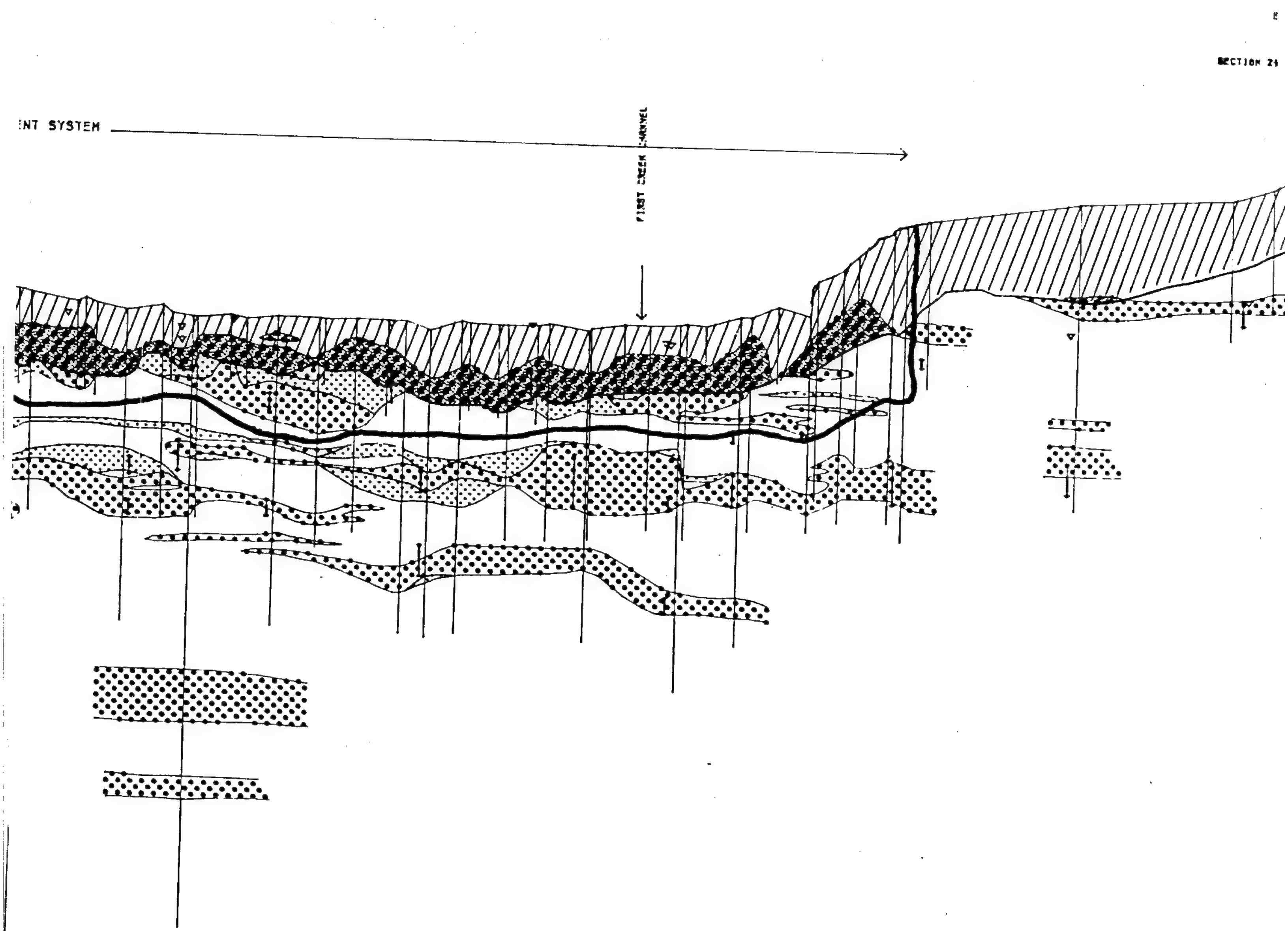


Figure 1.2-2
GEOLOGICAL CROSS SECTION AT THE
NORTH BOUNDARY CONTAINMENT SYSTEM

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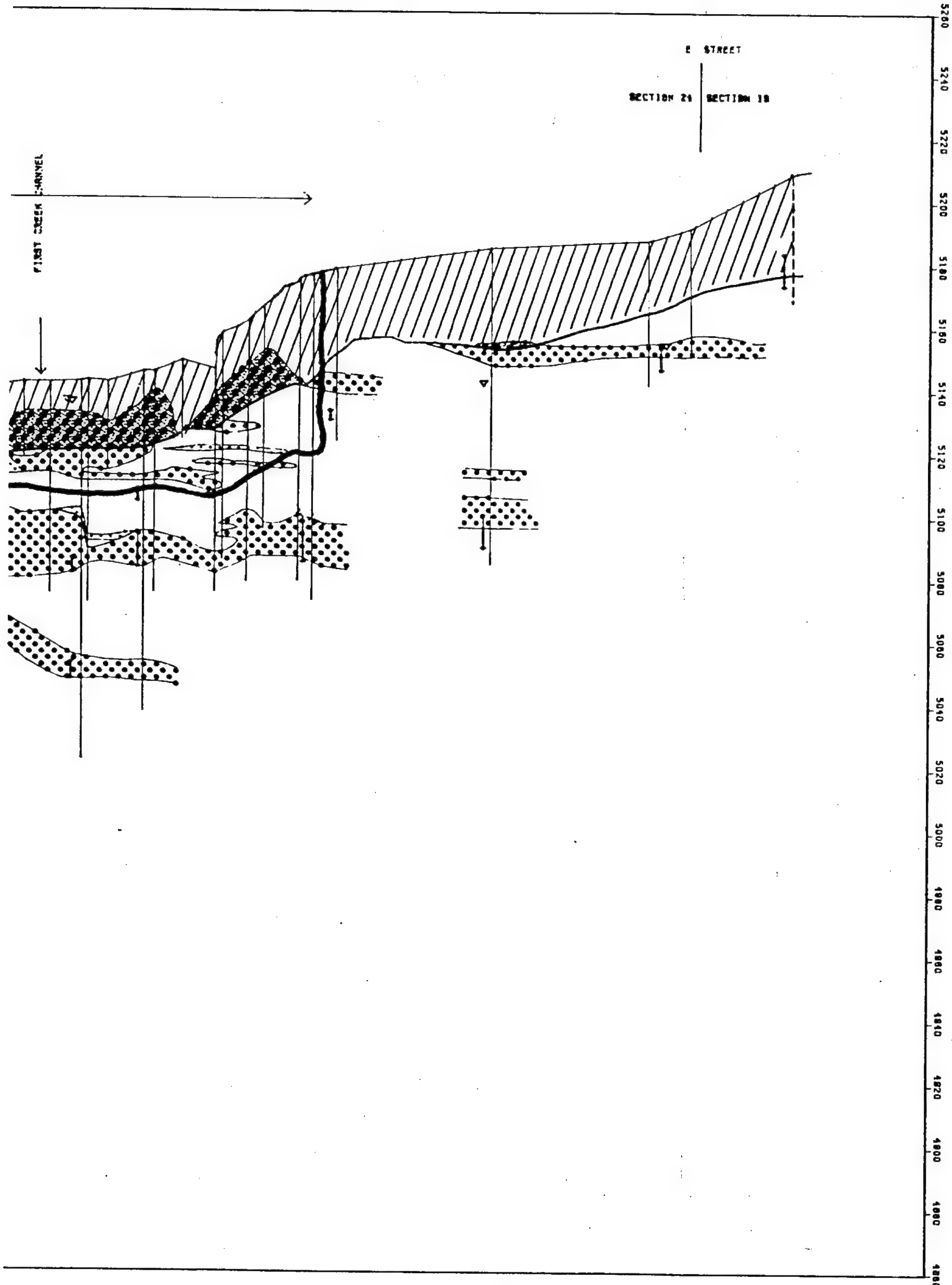
For Rocky Mountai
Aberdeen Proving Grou

EAST



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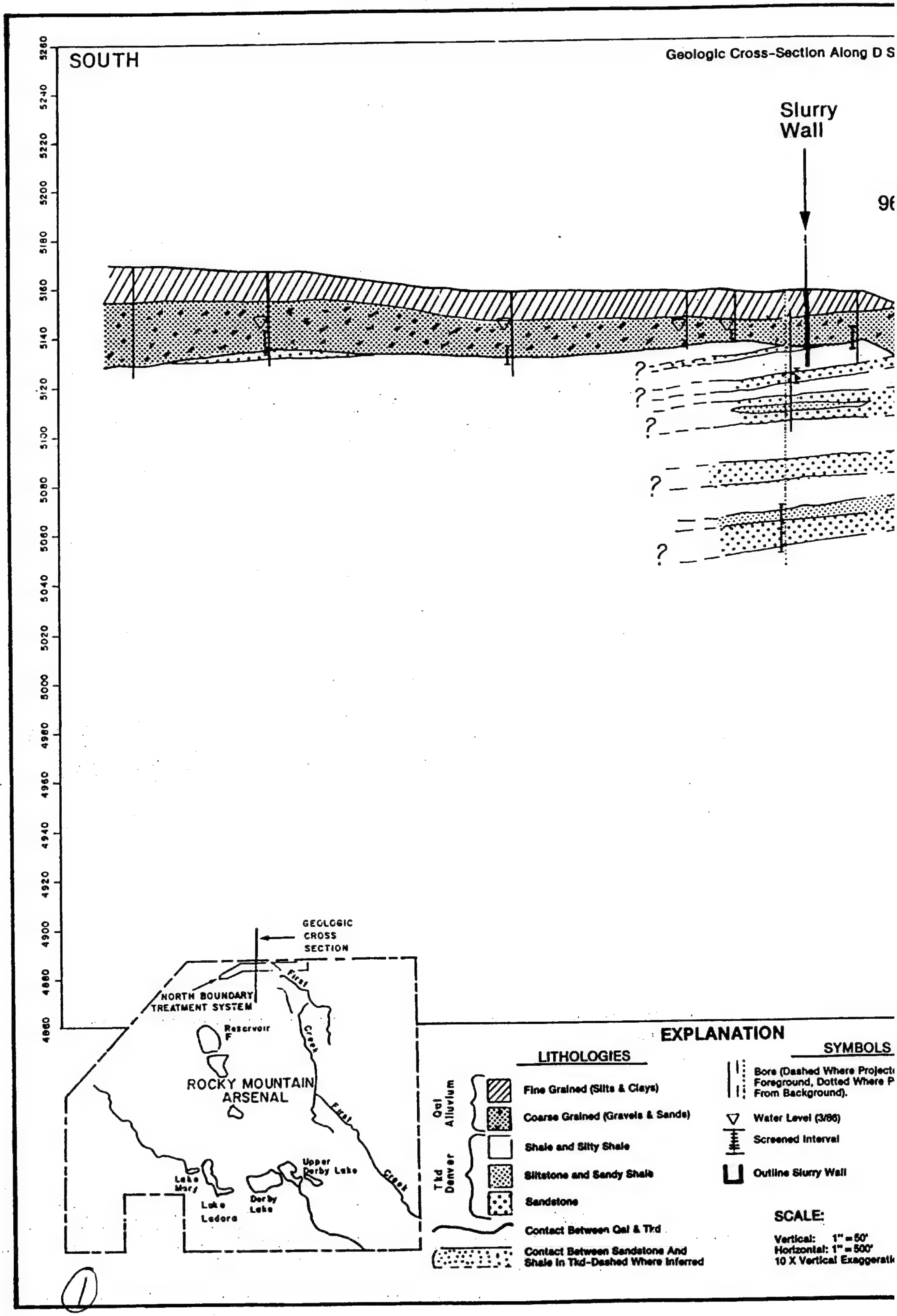
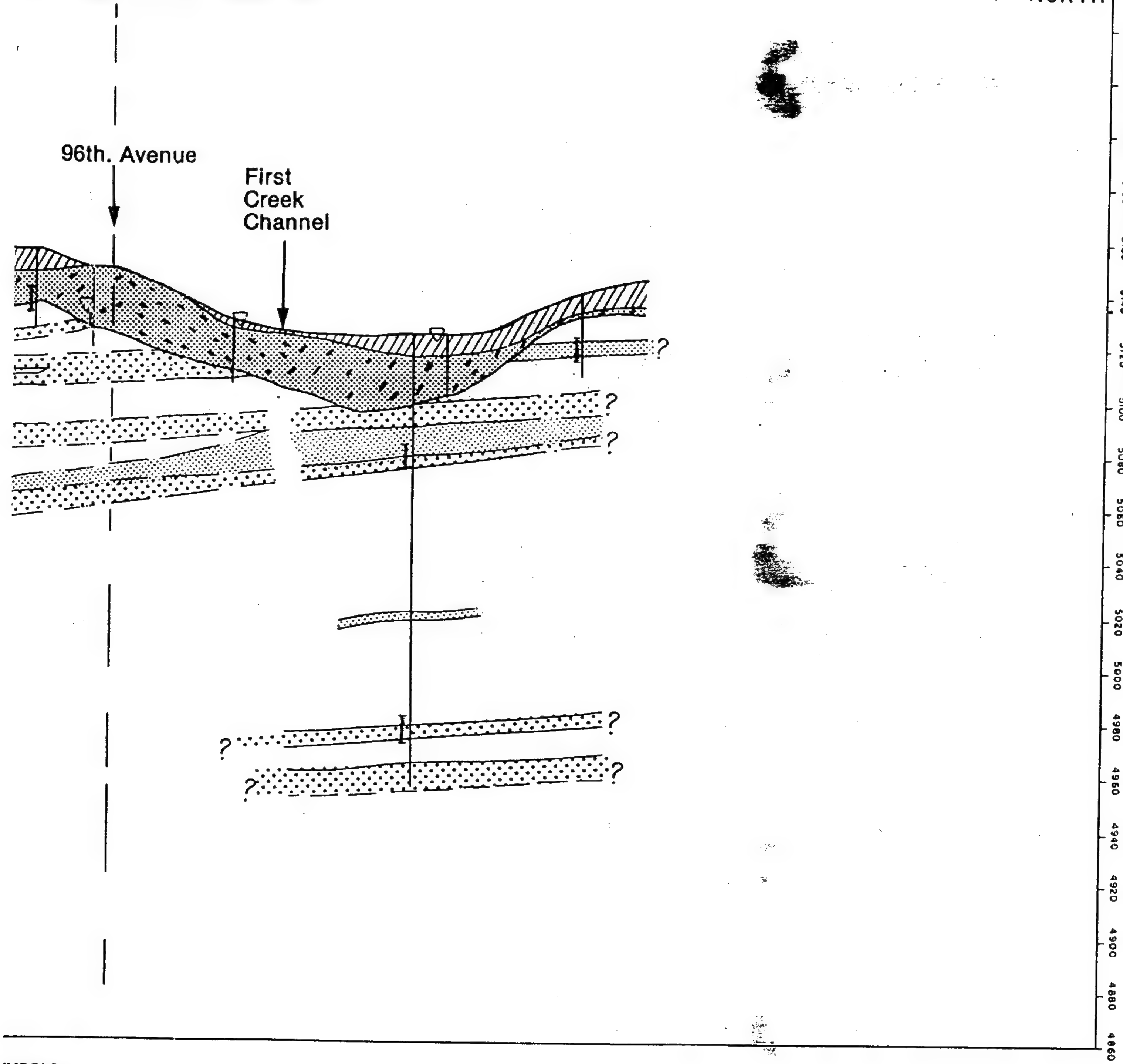

SOUTH
Geologic Cross-Section Along D S
Slurry Wall
96
5260
5240
5220
5200
5180
5160
5140
5120
5100
5080
5060
5040
5020
5000
4980
4960
4940
4920
4900
4880
4860
GEOLOGIC CROSS SECTION
NORTH BOUNDARY TREATMENT SYSTEM
Reservoir F
ROCKY MOUNTAIN ARSENAL
First Creek
First Creek
Lake Mary
Lake Ladora
Derby Lake
Upper Derby Lake
EXPLANATION
LITHOLOGIES
Qal Alluvium
Fine Grained (Silts & Clays)
Coarse Grained (Gravels & Sands)
Tkd Denver
Shale and Silty Shale
Siltstone and Sandy Shale
Sandstone
Contact Between Qal & Tkd
Contact Between Sandstone And Shale In Tkd-Dashed Where Inferred
SYMBOLS
Bore (Dashed Where Project
Foreground, Dotted Where P
From Background).
Water Level (3/86)
Screened Interval
Outline Slurry Wall
SCALE:
Vertical: 1" = 50'
Horizontal: 1" = 500'
10 X Vertical Exaggerati
1

\long D Street/Peoria Street, Looking West

NORTH



'MBOLS

ere Projected 100 Ft. From
ed Where Projected 100 Ft.
I).

' = 50'
' = 500'
Exaggeration

(2)

Figure 1.2-3
GENERALIZED GEOLOGIC CROSS-SECTION ACROSS THE NORTH BOUNDARY CONTAINMENT SYSTEM (Looking Due West)

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For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

1.2.2 HYDROLOGY

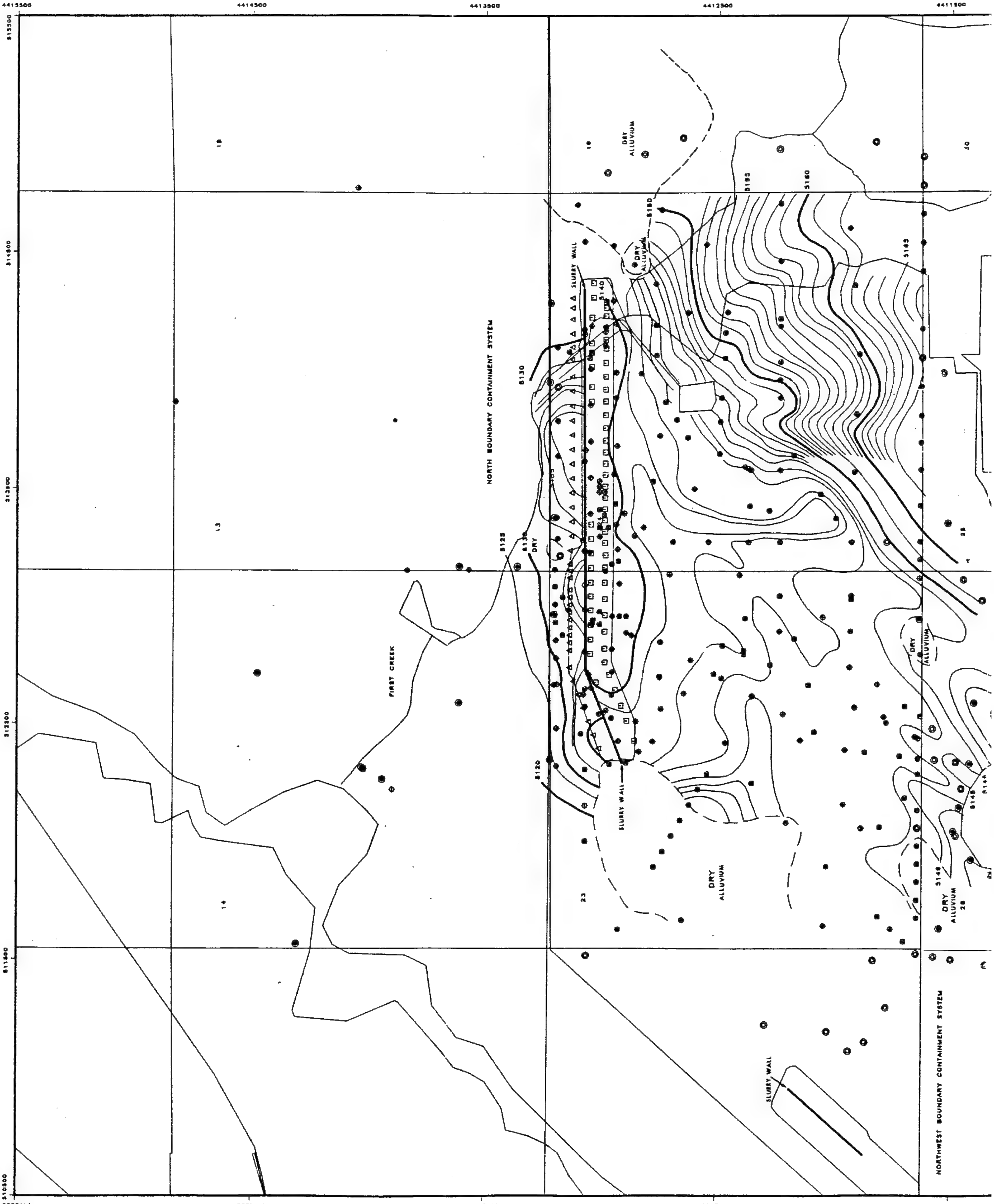
Near the north boundary of RMA the unconsolidated sediments are saturated to a maximum thickness of 25 ft with an average thickness of 15 ft. About 55 to 60 percent of the saturated unconsolidated sediments are sand and gravel and the remaining 40 to 45 percent are silt and clay. Horizontal flow rates through these alluvial sediments near the North Boundary (see cross-section Figures 1.2-2) are estimated at 250 to 325 gallons-per-minute (gpm) toward the north, under an average hydraulic gradient of 0.001 (Figure 1.2-4).

Previous aquifer tests performed on sediments near NBCS gave the following ranges for hydraulic conductivity (Ertec, 1981, RIC#81352R135; Black & Veatch, 1980, RIC#81266R25; May *et al.*, 1980, RIC#81266R48):

Sediment Type	Hydraulic Conductivity (gpd/ft^2) Range
Holocene	
Sand and gravel	8×10^2 to 2×10^4
Silt and clay	6 to 5×10^1
Denver Formation	
Sands	1×10^{-1} to 1×10^1
Shales and silts	$7 \times 10^{-3} \times 4 \times 10^{-1}$
Fractured shale	$2 \times 10^{-2} \times 4 \times 10^{-1}$

In general, the Denver Formation sandstones have a hydraulic conductivity of about three orders of magnitude less than the alluvial sediments. The shale has previously been assumed to have a much lower hydraulic conductivity than both the alluvium and Denver sandstones, but May, *et al.* (1980, RIC#81266R48) state that field slug tests and laboratory permeability tests have shown in some instances that permeability of fractured clay shale is comparable to that of the Denver sandstones.

The trend of the piezometric surface for the sandstones indicates overall net flow in the Denver aquifers to be to the north and northwest. Detailed knowledge of the hydrogeology and the localized ground water flow components in the Denver Formation, in the vicinity of the NBCS, is limited at present.



NORTH BOUNDARY CONTAINMENT SYSTEM
NORTHWEST BOUNDARY CONTAINMENT SYSTEM
SLURRY WALL
SLURRY WALL
SLURRY WALL
FIRST CREEK
DRY ALLUVIUM
DRY ALLUVIUM
DRY ALLUVIUM
DRY ALLUVIUM
DRY ALLUVIUM
DRY
5120
5125
5130
5140
5150
5155
5160
5145
5148
4415500
4414500
4413500
4412500
4411500

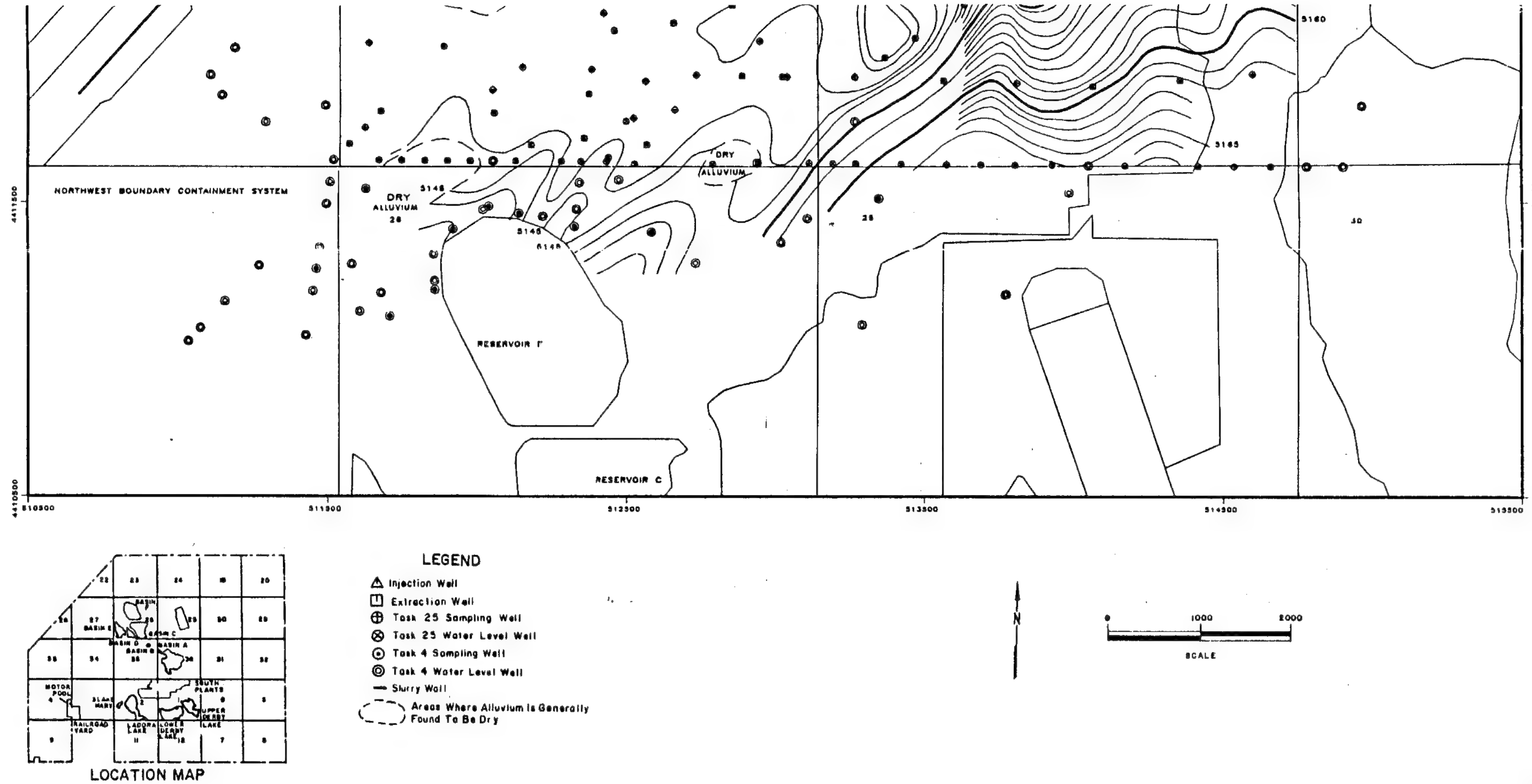


Figure 1.2-4
NORTH BOUNDARY CONTAINMENT SYSTEM ALLUVIAL WATER TABLE MAP
SOURCE: ESE, 1986

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Aberdeen Proving Ground, Maryland

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Detailed hydrogeologic analysis of the Denver Formation and alluvium in this task, will shed considerable light on the local hydrology and interaction between the alluvial and Denver aquifers.

1.2.3 SYSTEM CONSTRUCTION

The NBCS incorporates 54 dewatering wells upgradient from a soil-bentonite barrier to intercept the natural flow of ground water approaching the boundary. Thirty-five dewatering wells are screened in the alluvium and nineteen dewatering wells are screened in several of the Denver sand units. The pilot system was constructed in 1978 to be 1,500-ft long and had 6 dewatering and 12 recharge wells. The expansions were added in 1981 as "wings" to the original barrier and extend 3,840 ft due east and 1,400 ft south (70^{o}) west. The total soil-bentonite barrier is 6,740-ft long and approximately 3-ft wide, with a design permeability of 1×10^{-7} cm/sec or less. The barrier depth varies from 20 ft at the pilot system to over 40 ft along the eastern extension where a paleovalley incises into bedrock. The barrier is anchored in the Denver Formation. The system was designed to remove ground water flowing through the North Boundary area in both the alluvium and upper Denver sands, treat the ground water, and recharge it into the alluvium.

The dewatering wells are divided into three collection manifolds that intercept and dewater separate segments of the aquifer. Figure 1.2-5 shows the manifold alignment. Manifold A is the westward-most section of the system and contains 12 alluvial dewatering wells and 11 Denver sand wells. Manifold A primarily intercepts the DIMP plume. Manifold B, which intercepts the DBCP plume, begins east of D Street and includes 12 alluvial wells. Manifold C includes the easternmost section of the system alignment and is made up of 11 alluvial wells and 8 Denver wells. Manifold C intercepts trace concentrations of DBCP.

Ground water from each manifold is fed to a separate sump prior to entering the carbon adsorption treatment system. The use of separate adsorbers optimizes carbon bed life and removal efficiencies. The treatment system is made up of a cartridge-type prefilter three 30,000-lb upflow pulsed-bed

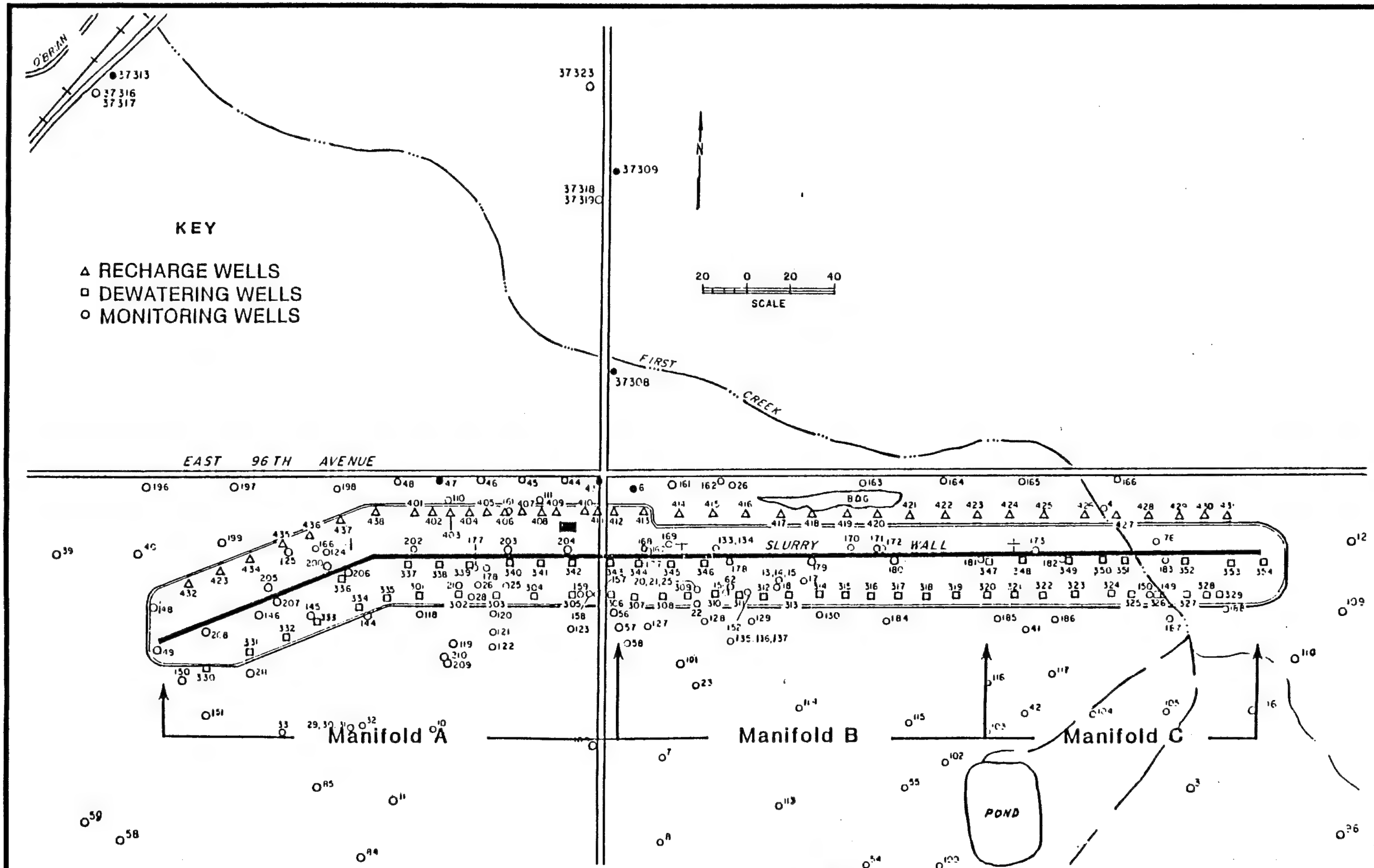

Figure 1.2-5
NORTH BOUNDARY CONTAINMENT SYSTEM

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Aberdeen Proving Ground, Maryland

carbon adsorbers, a carbon transfer and storage vessel, and a cartridge-type postfilter (Figure 1.2-6). Treated ground water is discharged to a common sump prior to recharge.

Recharge to the alluvium is accomplished through 38 recharge wells located downgradient from the slurry wall. The treated water is pumped to the 38 wells which are spaced to allow continued diffusion and dispersion in a manner similar to that which occurred prior to system implementation. All recharge is to the alluvium including treated ground water from the Denver sands dewatering wells.

The withdrawal and treatment components of the system have a theoretical capacity of 600 gpm, but this is limited in practice to 150 to 350 gpm by weather conditions and mechanical limitations. The recharge capacity of the system is lower than the practical withdrawal/treatment component and is limited by periodic plugging of wells and low permeability of sediments along the west end of the system.

1.2.4 SYSTEM OPERATION

There is substantial documentation of the operational history of the system. The plant operator maintains a log of operations and major events are documented on a weekly basis. The log covers operation, maintenance, and repair of all operating system components. During the 1983-1984 period covered by the 1985 Performance Report (Thompson, et al., 1985, RIC#86078R01), several problems were noted which affected overall system performance. These included: mechanical problems rendering some dewatering and recharge wells inoperable (freezing, lightning strikes), difficulty detecting that mechanical failures had taken place which in turn often led to the compounding of a problem, plugging of recharge wells with carbon fines, and failure of the system to handle severe flooding brought on by periodic storm events.

The system was designed to handle the total alluvial ground water flow toward the barrier. However, all of the listed problems, acting either individually, together, or with other undetected operational problems, have resulted in the system operating at less than design capacity. The

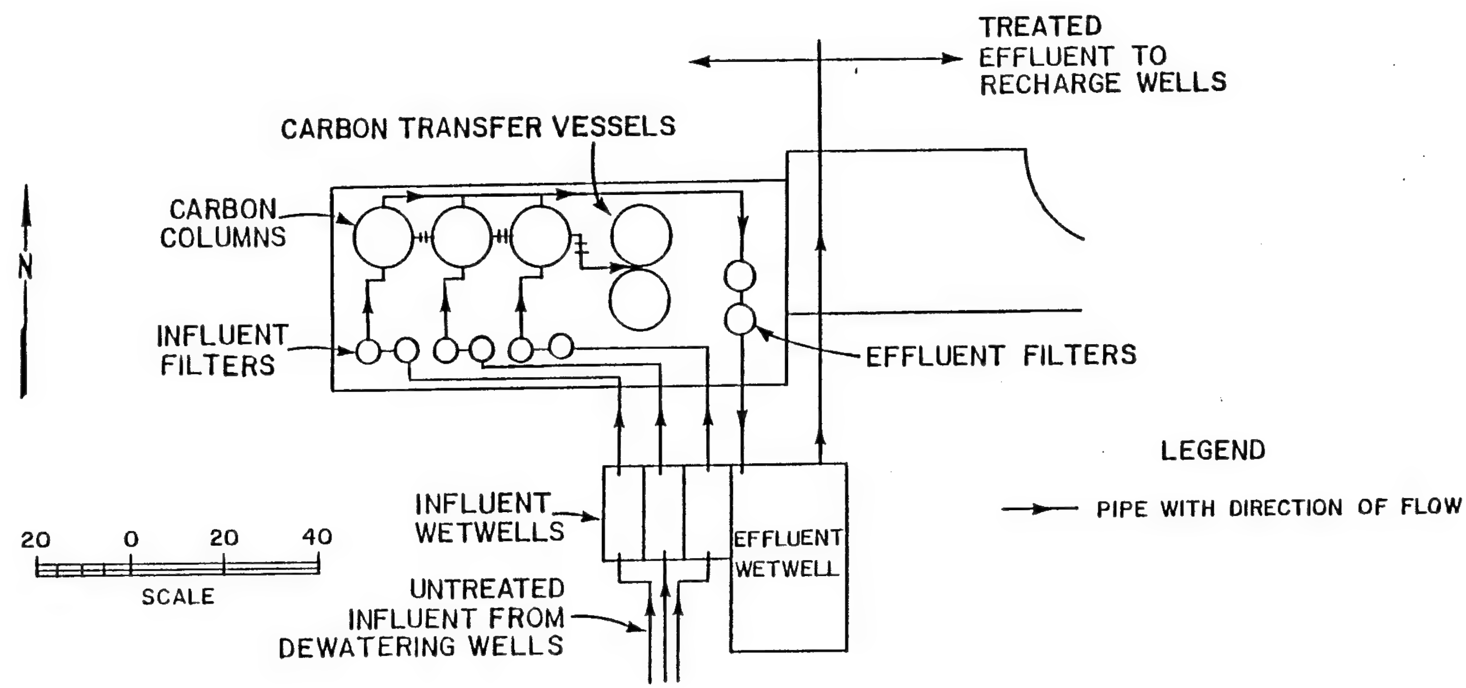

Figure 1.2-6
GROUND WATER TREATMENT FACILITY

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For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

resulting under-capacity of the system has lead to the development of a substantial differential head across the barrier wall which differs from the original design concept.

The operations log of the treatment systems shows, for the most part, the treatment facility is capable of removing the organic contaminants from the influent to detection limits. In addition, the blending of the treated effluent substantially reduces the overall concentrations of the inorganic contaminants, chloride and fluoride.

1.3 SUMMARY OF TECHNICAL APPROACH

The documentation of operational problems with the NBCS in the 1985 Performance Report (Thompson, et al., RIC#86078R01) and the continued detection of contaminants offpost have dictated that a more detailed performance evaluation be performed on the system. Task 36 will undertake that evaluation to fulfill the following objectives:

- o Assess the dewatering and recharge components of the system through a review of the operational data, performance testing of the components numerical modeling and evaluation of additional geotechnical data;
- o Assess the configuration of the Denver Formation sandstones and evaluate their hydrologic characteristics, especially in the area of the Pilot System, through the acquisition and evaluation of additional geologic and hydrologic data;
- o Assess the physical condition of the soil-bentonite barrier wall through in situ and laboratory testing, especially in areas suspected of having problems. The testing will consider primarily the physical characteristics of the wall;
- o Develop recommendations for integrated operational modifications and/or design changes that will help mitigate the documented problems in the NBCS and achieve positive control of contaminated ground water in both alluvial and Denver aquifers. Operating goals will include recharge capability for 125 percent of dewatering flow

distributed so as to minimize hydrologic impact. These goals will consider normal well efficiency and historical down-time factors: and

- Assess the effectiveness of the treatment plant by conducting a literature review and collecting water quality data from the plan. The approach for this component of the assessment is addressed in a Letter Technical Plan included in Appendix A of this report.

To achieve the listed objectives, an integrated geotechnical program will be undertaken to collect the necessary geologic, hydrologic, physical, and chemical data. This will include the installation of additional water level and/or water quality monitoring wells, bedrock and soil sampling and logging, and barrier sampling. Several in situ tests and laboratory tests are also proposed. Details of these tests are described in Section 3.0. This program will interface with the geotechnical programs for Tasks 4, 25, 39, and Task 44 where appropriate to minimize the duplication of effort. The data acquired through the geotechnical program will be integrated with the existing data network and will be evaluated with a historical perspective to fully assess all of the problems noted. The data will be used to produce contamination maps and plots, hydrographs, water level maps, geologic cross sections, and maps to characterize the three dimensional ground water flow and contaminant transport in the vicinity of the NBCS. The data from the operational evaluation and physical testing of the barrier will be used to produce plots to determine operational parameters for the system.

2.0 DATA COMPILATION

Task 36 will be an extension of previous geotechnical work carried out over the past 30 years. This portion of the program will be conducted in two discrete phases. The first phase will consist of a compilation of data and results from past and ongoing programs. This work will involve reviewing all pertinent information on file at the RMA Resource Information Center (RIC) and the Program Managers Office-Rocky Mountain Arsenal (PMO-RMA) as well as interviewing technical experts in the PMO-RMA, U.S. Corps of Engineers (COE), U.S. Environmental Protection Agency (USEPA), and other agencies with a knowledge of the NBCS. Based on this data, Task 36 will evaluate wells that have been sampled in the past, utilize previous aquifer tests, analyze historic onpost contaminant plumes, and to develop a overall geological and hydrological understanding of the NBCS area based on existing data. This review will be fundamental to identifying data gaps and to the final assessment of the design and operation of the NBCS. All data will be evaluated for its applicability to the barrier investigation, the Denver Sands evaluation and the analysis of the dewatering/recharge system.

The second phase of data compilation will consist of compiling new water level and water quality data into a comprehensive data base. This information will be supplemented by additional geologic data, evaluations of dewatering and recharge wells, and barrier investigations. This second phase will supply all the additional data required to perform a reliable assessment of all major NBCS components and to conceptually identify any response actions that may be required for more efficient operation.

3.0 GEOTECHNICAL PROGRAM

The purpose of the geotechnical program will be to acquire the necessary geologic, hydrologic, chemical, and engineering data to adequately address the overall effectiveness of the NBCS. Field activities will include drilling boreholes, collecting barrier and geologic samples, installing ground water monitoring wells, measuring water levels, obtaining ground water quality samples, and conducting aquifer tests. Affiliated laboratory activities will include testing of geologic samples and barrier samples to determine physical properties such as composition, porosity permeability, and grain size.

3.1 SUBSURFACE INVESTIGATION PROGRAM

Ground water levels and ground water quality samples are being taken from a network of existing wells as part of Tasks 4, 25, and future Task 44. Information collected in these field programs will be utilized where appropriate to fulfill the data requirements for this task. In addition, the site selection process for the placement of new monitor wells for this task will be coordinated with the needs of other tasks so that new well installation is optimized. The data collected from these new wells will be compatible with the requirements of all tasks involved because the concurrent geotechnical programs will utilize the same field and management teams, techniques, and procedures.

The construction of existing wells has been evaluated for sampling suitability as part of Tasks 4 and 25. Those rating efforts have been used to select a network of existing wells which are suitable for use in this program. In addition to utilizing the construction information, such as screened interval and construction materials, the wells utilized for the Task 36 evaluation will be evaluated for sampling history and geographic location after completion of the Task 25 First Quarter Sampling Program.

Tables 3.1-1 and 3.1-2 and Figure 3.1-1 show the existing wells selected for Tasks 4 and 25 which can be used for water levels and water quality sampling

Table 3.1-1. Task 25 Monitoring Network Selected for the North Boundary Containment System (Page 1 of 6)

Well Number	Aquifer*	Classification for Chemical Sampling	Water Level	Chemical Sampling	Sampled Previously
23002	A1	Q	X		
23003	A1	U	X		
23004	A1	Q	X	X	X
23006	A1	U	X		
23007	A1	P	X		
23008	A1	Q	X	X	X
23009	A1	Q	X		x
23010	A1	Q	X	X	X
23011	A1	Q	X	X	X
23012	A1	U	X		
23013	A1	Q	X	X	X
23014	A1	Q	X	X	X
23015	A1	Q	X		X
23016	A1	U	X	X	X
23025	A1	Q	X		
23026	A1	Q	X		
23029	A1	Q	X	X	
23030	A1	U	X		
23033	A1	U	X		
23034	A1	Q	X		
23036	A1	Q	X		
23038	A1	Q	X		
23039	A1	Q	X	X	
23040	A1	Q	X		
23043	A1	U	X	X	X
23044	A1	U	X		
23045	A1	U	X	X	
23046	A1	U	X		
23047	A1	U	X	X	X
23048	A1	Q	X	X	
23050	A1	U	X	X	X
23051	A1	U	X		
23052	A1	Q	X	X	X
23053	A1	Q	X		
23054	D	Q	X		
23055	A1	U	X		
23056	A1	Q	X		
23057	A1	Q	X	X	X
23058	A1	Q	X		
23059	A1	Q	X		
23060	A1	P	X		
23061	A1	Q	X		
23062	A1	U	X		

Table 3.1-1. Task 25 Monitoring Network Selected for the North Boundary Containment System (Continued, Page 2 of 6)

Well Number	Aquifer*	Classification for Chemical Sampling	Water Level	Chemical Sampling	Sampled Previously
23063	A1	Q	X		
23064	A1	Q	X		
23066	A1	Q	X		
23067	A1	Q	X		
23070	A1	Q	X		
23072	A1	U	X		
23079	A1	U	X		X
23084	A1	U	X		
23085	A1	U	X	X	X
23092	A1	U	X		
23094	A1	Q	X		
23096	A1	Q	X		
23097	A1	Q	X	X	X
23099	A1	Q	X		
23101	A1	U	X		
23102	A1	U	X	X	X
23106	A1	U	X	X	X
23107	A1	P	X		
23109	A1	Q	X		
23110	A1	Q	X		
23111	A1	Q	X		
23118	A1	Q	X	X	
23119	A1	Q	X	X	
23120	A1	Q	X	X	X
23121	A1	Q	X		
23122	A1	Q	X		
23123	A1	Q	X	X	X
23124	A1	U	X		
23128	A1	Q	X		
23129	A1	Q	X		
23131	A1	P	X		
23132	A1	Q	X		
23134	A1	U	X		
23135	A1	U	X		
23136	A1	Q	X		
23137	A1	Q	X		
23140	A1	Q	X		
23141	A1	Q	X		
23143	A1	Q	X		
23144	A1	Q	X	X	
23145	A1	Q	X		X
23146	A1	Q	X		

Table 3.1-1. Task 25 Monitoring Network Selected for the North Boundary Containment System (Continued, Page 3 of 6)

Well Number	Aquifer*	Classification for Chemical Sampling	Water Level	Chemical Sampling	Sampled Previously
23148	A1	Q	X		
23149	A1	Q	X		
23150	A1	Q	X	X	
23151	A1	Q	X	X	
23157	A1	Q	X		
23160	A1	Q	X	X	X
23161	D	A	X	X	X
23162	D	A	X		
23173	D	A	X	X	
23174	D	A	X	X	X
23176	A1	P	X		
23178	A1	Q	X		
23181	D	A	X	X	
23184	D	A	X		X
23189	A1	A	X	X	
23193	D	A	X		
23196	A1	P	X	X	X
23197	A1	P	X	X	
23198	A1	P	X	X	X
23199	A1	Q	X		X
23200	D	P	X	X	X
23201	D	P	X	X	
23202	A1	Q	X	X	X
23203	A1	P	X	X	X
23204	A1	P	X	X	X
23205	A1	P	X	X	
23207	A1	P	X		
23208	A1	U	X	X	
23209	D	Q	X	X	X
23210	D	Q	X	X	
23211	A1	P	X	X	
24001	A1	P	X		
24002	A1	P	X		
24003	A1	Q	X	X	
24004	A1	Q	X		X
24007	A1	Q	X		X
24008	A1	Q	X	X	X
24009	A1	Q	X		
24010	A1	Q	X	X	X
24013	A1	Q	X	X	X
24014	A1	Q	X		
24015	A1	Q	X		
24016	A1	Q	X		

Table 3.1-1. Task 25 Monitoring Network Selected for the North Boundary Containment System (Continued, Page 4 of 6)

Well Number	Aquifer*	Classification for Chemical Sampling	Water Level	Chemical Sampling	Sampled Previously
24017	A1	Q	X	X	X
24018	A1	Q	X		
24019	A1	Q	X		
24020	A1	Q	X		
24021	A1	Q	X		
24022	A1	Q	X		
24023	A1	Q	X	X	X
24024	A1	Q	X	X	X
24025	A1	Q	X		
24027	A1	Q	X	X	X
24043	A1	Q	X		
24045	A1	Q	X		
24048	A1	Q	X		
24049	A1	Q	X	X	X
24050	A1	Q	X		
24051	A1	Q	X		
24052	A1	Q	X		
24053	A1	Q	X		
24054	A1	Q	X		
24055	A1	Q	X		
24056	A1	Q	X		
24057	A1	Q	X		
24062	A1	Q	X		
24063	A1	Q	X	X	X
24064	A1	Q	X		
24065	A1	U	X		
24080	A1	Q	X		
24081	A1	Q	X	X	X
24083	A1	Q	X		
24085	A1	Q	X		
24086	D	Q	X	X	
24087	A1	Q	X		
24088	A1	Q	X	X	
24089	A1	Q	X		
24090	A1	Q	X		
24091	A1	U	X		
24092	A1	Q	X		
24093	A1	Q	X		
24094	A1	Q	X	X	
24095	A1	Q	X		
24096	A1	Q	X	X	
24097	A1	Q	X		
24098	A1	Q	X		
24099	A1	Q	X		X

Table 3.1-1. Task 25 Monitoring Network Selected for the North Boundary Containment System (Continued, Page 5 of 6)

Well Number	Aquifer*	Classification for Chemical Sampling	Water Level	Chemical Sampling	Sampled Previously
24100	A1	Q	X		
24101	A1	Q	X		X
24102	A1	Q	X		
24103	A1	Q	X		
24104	A1	Q	X		
24105	A1	Q	X		
24106	A1	Q	X	X	
24107	A1	Q	X	X	
24108	A1	Q	X	X	
24109	D	Q	X	X	
24110	A1	Q	X	X	
24111	A1	Q	X	X	X
24112	A1	Q	X		
24113	A1	Q	X	X	X
24114	A1	Q	X		
24115	A1	Q	X	X	X
24117	A1	Q	X		
24120	D	Q	X	X	
24121	A1	Q	X		
24122	A1	Q	X		
24123	A1	Q	X		
24124	D	Q	X	X	X
24125	D	Q	X		
24126	D	Q	X		
24127	D	Q	X	X	X
24128	D	Q	X	X	
24129	D	Q	X		
24130	D	Q	X		X
24135	D	Q	X		X
24137	D	P	X		
24148	A1	Q	X		
24149	A1	P	X		
24151	A1	Q	X		
24154	A1	Q	X		
24156	D	P	X		
24161	A1	P	X	X	
24162	A1	P	X	X	X
24163	A1	P	X	X	X
24164	A1	P	X	X	
24166	A1	P	X	X	
24167	D	Q	X	X	X
24168	D	Q	X	X	X
24169	A1	Q	X		

Table 3.1-1. Task 25 Monitoring Network Selected for the North Boundary Containment System (Continued, Page 6 of 6)

Well Number	Aquifer*	Classification for Chemical Sampling	Water Level	Chemical Sampling	Sampled Previously
24170	Al	P	X	X	
24171	D	Q	X	X	X
24172	D	P	X	X	
24174	D	P	X	X	
24175	D	P	X	X	
24176	Al	P	X	X	
24177	Al	Q	X	X	
24179	Al	P	X	X	
24180	Al	Q	X	X	X
24181	Al	Q	X	X	
24182	Al	Q	X	X	
24183	Al	P	X	X	
24184	Al	P	X	X	X
24186	Al	Q	X	X	X
24187	Al	Q	X	X	
24188	Al	P	X	X	
37306	Al	A	X	X	
37316	D	A	X	X	X
37317	Al	A	X	X	X
37318	Al	A	X	X	X
37319	D	A	X	X	
37321	D	A	X	X	X
37322	D	A	X	X	X
37323	Al	A	X	X	X
37327	Al	A	X	X	X

* = Aquifer in which well was screened.
Al = Alluvial
D = Denver

Classification for Chemical Sampling

Q = Questionable
P = Possible
A = Acceptable
U = Unacceptable

Source: ESE, 1986.

Table 3.1-2. Task 4 Monitoring Network for the North Boundary Containment System

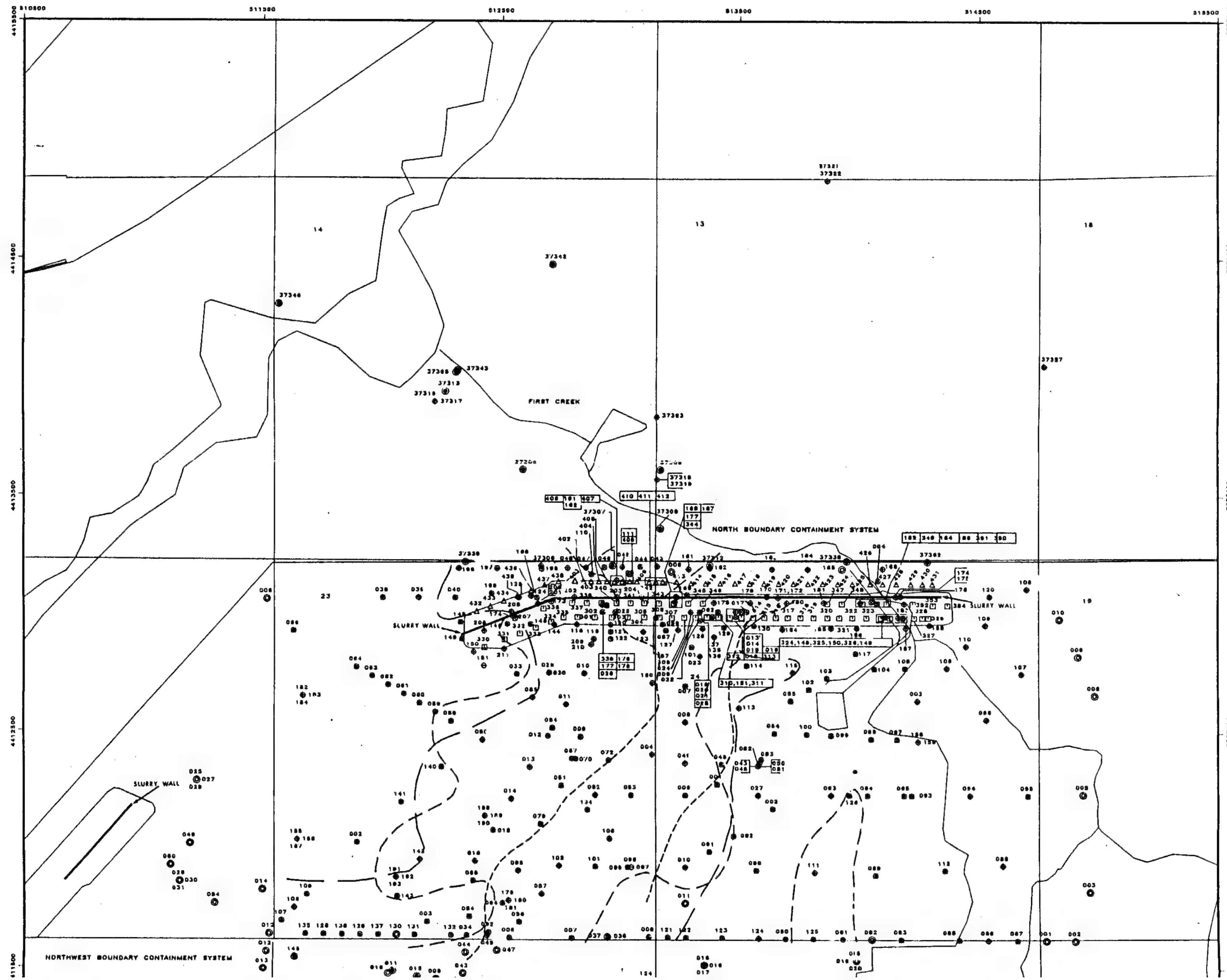
Well Number	Aquifer*	Classification for Chemical Sampling	Water Level	Chemical Sampling	Sampled Previously
23049	Al	Q	X		
23095	Al	U	X		
23108	Al	U	X		
23125	Al	Q		X	
23142	Al	Q	X		
23166	Al	P	X		X
23177	D	A	X	X	X
23179	Al	A	X		
23180	D	A	X		
23182	Al	A	X		
23183	D	A	X		
23185	Al	A	X		
23186	D	A	X		
23187	D	A	X		
23188	Al	A	X		
23190	D	A	X		
23191	Al	A	X		
23192	D	A	X		
24196	D	P	X		
24150	D	P	X		
24158	D	P	X		
24159	D	A	X		
24178	A	P	X	X	
24185	A	P	X		

* = Aquifer in which well was screened
Al = Alluvial
D = Denver

Classification for Chemical Sampling

Q = Questionable
P = Possible
A = Acceptable
U = Unacceptable

Source: ESE, 1986.


NORTH BOUNDARY CONTAINMENT SYSTEM
NORTHWEST BOUNDARY CONTAINMENT SYSTEM
FIRST CREEK
SLURRY WALL
SLURRY WALL
SLURRY WALL
13
14
18
19
23
24

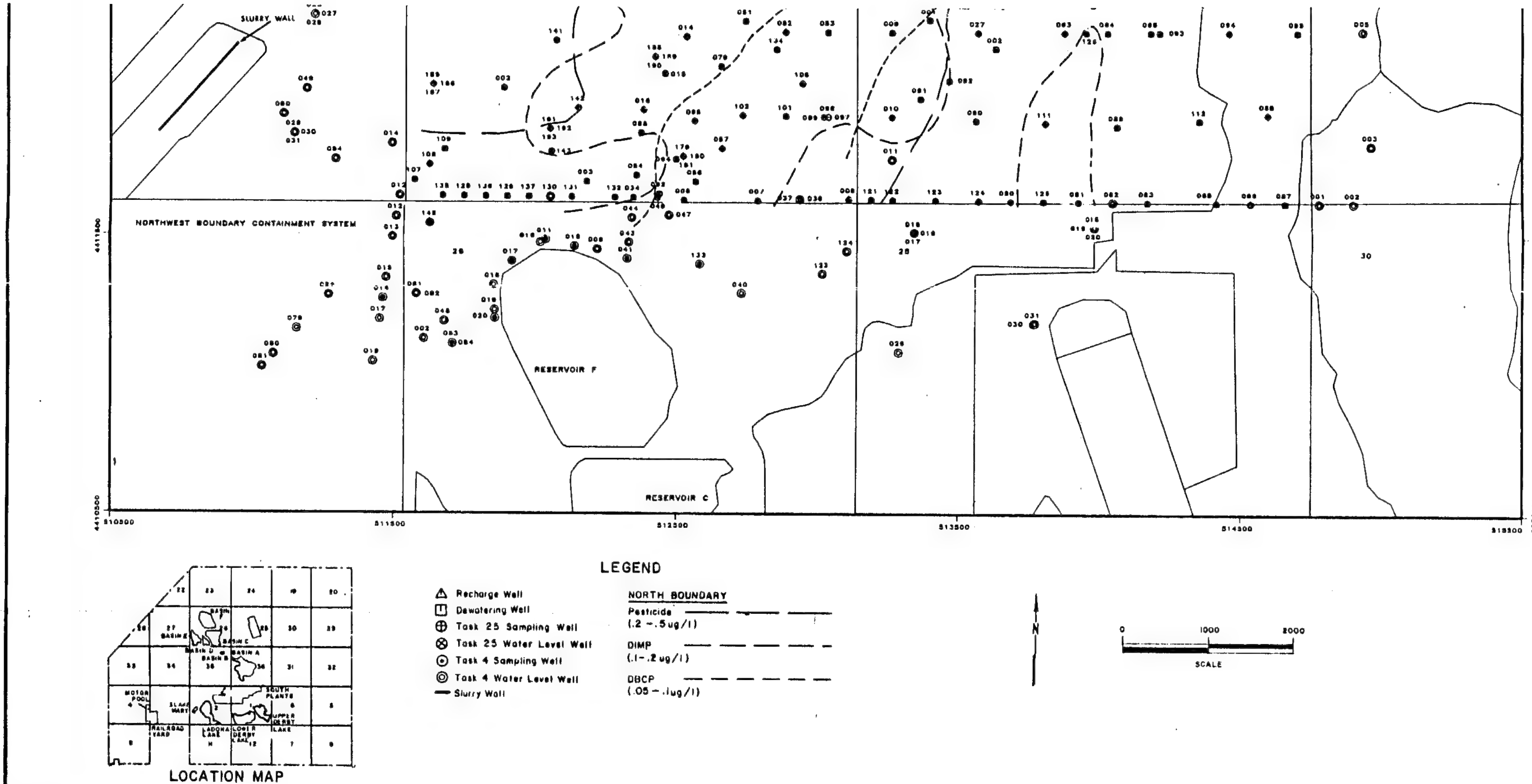


Figure 3.1-1
NORTH BOUNDARY CONTAINMENT SYSTEM MONITOR NETWORK WITH PLUMES

SOURCE: ESE, 1986

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

in this task. A construction and installation evaluation system was established in Task 4 and utilized in the classification of wells for Task 25.

The Task 25 wells were classified as Acceptable, Possibly Acceptable, or Questionable, based on construction criteria; however, some wells classified as Unacceptable were included (see Tables 3.1-1 through 3.1-2) in the monitoring network. These wells were only chosen because they had been sampled in the past and a continuity of data was deemed important. Several of these wells will be replaced by new wells where they are in critical locations.

The Task 36 well installations will supplement the existing network cited above and the proposed sites which will be installed under Tasks 25 and 39. It is estimated that approximately 16 additional sites and a total of 30 water quality wells will be installed based on a preliminary review of existing data. The majority of these wells will be located downgradient of the barrier. This network will be augmented by a system of approximately 10 to 20 water level measuring wells which will be placed closely around the soil-bentonite barrier.

A preliminary round of water quality and water level samples will be taken from a number of the first wells installed to help pinpoint the locations of additional wells and direct the barrier sampling program. After this initial round, water quality and water level sampling will be incorporated into a comprehensive network that will include new and existing wells from Task 4, 25, and 39.

The Task 36 network of boreholes and wells will be selected to provide additional water level and water quality data, define geologic and hydrologic conditions close to and within the barrier, and examine possible routes of contaminant transport near the NBCS. This data will be gathered in sufficient detail to adequately evaluate the dewatering/ recharge system, the soil-bentonite barrier, and Denver Sands units.

3.1.1 RATIONALE FOR INVESTIGATION

New monitoring wells and barrier investigations have been proposed to supplement data from the existing well network and to assess the integrity of the soil-bentonite barrier. The specific location and rationale for sites will be outlined in Letter Technical Plans that will be incorporated in Appendix A. The investigations are broken down into sites upgradient of the system, sites downgradient of the system, and actual barrier investigations. This breakdown is convenient because the rational for each of these subcategories are similar. The sites chosen for each group are based on supplementing data from Task 4 and 25 and the evaluation of all data accumulated under Phase I of the Data Compilation Program described in Section 2.0. The program is planned to provide the additional geologic, hydrologic, and water quality data needed to adequately evaluate the different components of the NBCS.

3.1.1.1 Barrier Investigation

Actual investigation of the soil-bentonite barrier will be directed by historic and new data on contaminant distributions and water levels around the NBCS. The proposed sampling plan will follow guidelines set forth in Section 3.8.2 and is intended to assess the overall condition of the barrier, particularly in the vicinity of the pilot barrier. It is estimated that approximately five to ten sample locations will be required to provide a statistically representative view of the barrier's condition. The testing program for barrier samples is outlined briefly in Section 3.9.1.

The barrier assessment also includes the installation of water level monitoring wells immediately around the barrier (Section 3.3) and the sampling of fractured bedrock units beneath the barrier (Section 3.8.1). This data will supplement the actual barrier investigation to provide a comprehensive assessment of the barrier's effectiveness in retarding ground water flow.

3.1.1.2 Sites Downgradient of Barrier

Several new downgradient monitor wells have been proposed to fill gaps in the existing downgradient well network. At this time, 11 sites have been proposed. After Phase I of the Data Compilation portion of the study is

complete and timely comments have been reviewed, additional sites will be proposed and preliminary sites may be shifted to ensure that data is obtained in areas where it is most needed. The specific location and types of wells proposed for each site will be documented in Letter Technical Plans that will be included in Appendix A.

Downgradient sites will consist of both onpost and offpost sites. For offpost sites, consideration has been given to ease of access and land-use patterns. The monitoring needs for Tasks 25, 39, and future Task 44 are also incorporated into the siting selection. Monitor wells to be installed by all three tasks have been assembled into a consolidated drilling program to maximize field efficiency and obtain more favorable rates from drillers and other subcontractors.

The Task 36 downgradient wells will be sited to meet the following objectives:

- Provide water level and water quality data in sufficient detail to evaluate system performance;
- Define in detail the geologic and hydrologic conditions downgradient of the NBCS, and how this information correlates with data at and upgradient of the barrier; and
- To help determine possible routes of contaminant transport under, around, or through the barrier wall.

Downgradient sites are summarized in Table 3.1-3 and shown in Figure 3.1-2. Proposed site numbers were assigned to sites sequentially and do not reflect any inherent priority. Additional site rationale is outlined in ESE's Letter Technical Plan of November 26, 1986 (Section 10.0). At this time 11 sites have been chosen which are concentrated in the offpost area or onpost immediately downgradient from the system. Six offpost sites, (E-34, E-39 through E-42, E-63) have been chosen because of the long expected lead time for permit acquisition. The placement of three (E-34, E-39, E-63) of these six sites are nearly certain. E-39 and E-63 are cluster well sites consisting of one alluvial and two new Denver wells in vital locations (lacking geologic, hydrologic, and water quality data), while E-34 is a cluster well site of two Denver wells at existing alluvial well site 37338.

Table 3.1-3. List of Proposed Well and Borehole Sites

Site	Location	Owner
E-32	NE/4, NE4 Section 23 (23043)	RMA
E-33	NW/4, NW/4 Section 24 (24026 or 24163)	RMA
E-34	SE/4, SW/4 Section 13 (37338)	Adams County
E-35	NE/4, NE/4 Section 24 (bore only)	RMA
E-39	SE/4, SW/4 Section 14	Private
E-40	SW/4, SE/4 Section 14	Private
E-41	SE/4, SE/4 Section 14	Private
E-42	SE/4, SE/4 Section 14	Private
E-63	SW/4, SW/4 Section 13	Private
E-66	NW/4, NE/4 Section 23	RMA
E-67	NE/4, NE/4 Section 23	RMA

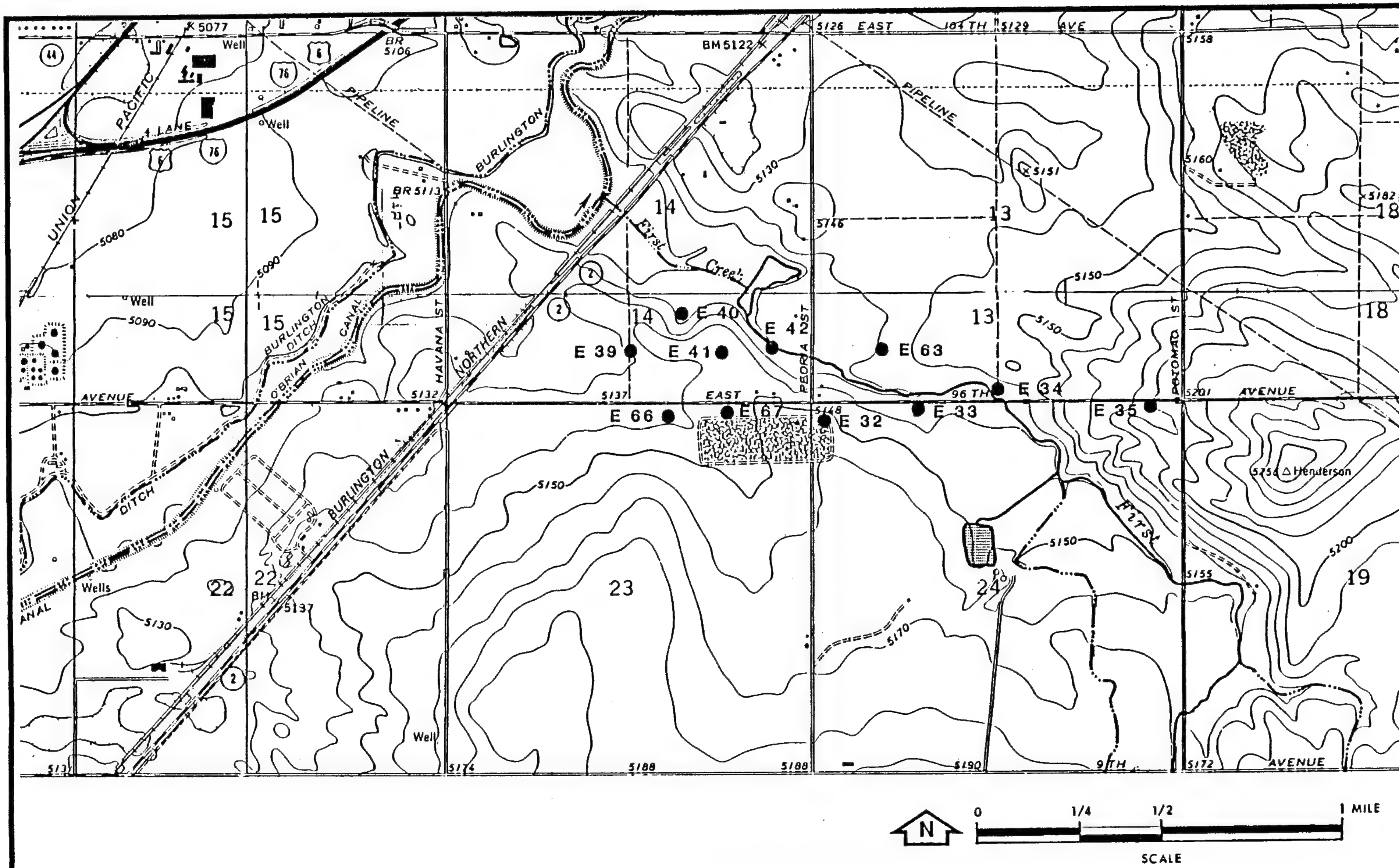


Figure 3.1-2
PROPOSED SITES FOR NEW MONITOR WELLS
AND BOREHOLES FOR TASK 36

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

The remaining three offpost sites (E-40, E-41, E-42) are more flexible sites. It is probable that not all three sites will need to be completed to provide the data required. Final selection or elimination of sites will be determined by the results from the Task 25 First Quarter Sampling Program and Phase I of the Data Compilation portion of this study.

Five onpost sites have been selected to date. E-32 and E-33 are each two Denver well clusters at existing alluvial well sites 23043 and 24026 (or 24163), respectively. Both of these sites fill gaps in geologic, hydrologic, and water quality data networks. E-35 is the site of a borehole to be drilled into bedrock and abandoned. E-67 and E-66 are sites for Denver well clusters at existing alluvial wells 23047 and 23197, respectively, where geologic information on the Denver aquifer is sparse.

The specific location of the remainder of the onpost downgradient sites will be chosen based on a combination of the following:

- The detailed geologic study to be initiated under Phase I of Data Compilation (Section 2.0);
- The results of the First Quarter Sampling Program from Task 25 (field work is already complete); and
- Preliminary assessment of the historical water level and water quality data presented in the 1984 Performance Report on the NBCS; and
- Consideration of timely comments from Memorandum of Agreement (MOA) parties.

The delay in finalizing the remaining sites is necessitated by the desire to incorporate as much detailed data as possible to meet the exacting location needs of this task. All sites that deviate from this preliminary siting will be addressed in Letter Technical Plans and incorporated into Appendix A.

All preliminary sites downgradient are described in more detail below:

Site E-32 is a site for the installation of two Denver wells at the location of alluvial well 23043 near the intersection of "D" Street and 96th Avenue. The site is on RMA and is about 50 ft west of the east line and 50 ft south of the north line in the NE/4, NE/4 of Section 23. This site is needed to characterize the geology, hydrology, and contaminant plumes in the Denver aquifer downgradient from the NBCS.

Site E-33 is located just south of 96th Avenue in the NW/4, NW/4 of Section 24 at the site of existing alluvial well 24026 on RMA. This location is about 800 ft east of the west line and 50 ft south of the north line of Section 24. Two Denver wells are proposed to characterize the geology, hydrology, and chemistry in the Denver sandstones north of the NBCS. An alternative site for Site 33 could be 700 ft further east at existing well 24163 or at a more appropriate site between 24026 and 24163 as determined from the detailed geology to be done in the Preliminary Assessment.

Site E-34 is offpost at existing alluvial well 37338 on the north side of 96th Avenue in the SE/4, SW/4 of Section 13. The site is about 2,500 ft east of the west line and 20 ft north of the south line and is on Adams County Highway Department right-of-way. Two wells will be installed to identify the geology and hydrology of the sandstones in the Denver Formation and to determine water chemistry in this part of the aquifer.

Site E-35 is on RMA approximately 4,800 ft east of the west line and 50 ft south of the north line in the NE/4, NE/4 of Section 24. A borehole is proposed at this site to characterize the Denver Formation geology.

Site E-39 is an offpost site located on property denoted by tax record 1721-14-0-05-005 in the SE/4, SW/4 of Section 14 owned by:

City of Commerce City
% Gregg Clements
4407 E. 60th Avenue
Commerce City, Colorado 80022
(303) 289-3701

The area is currently being dryland wheat farmed by Hickey Farm.

% Charles Hickey
3240 Jay Street
Wheatridge, Colorado 80033
(303) 233-9003

A 50-ft easement and corridor of access has been requested for the eastern property line of Block 5 of the Adco Industrial Park Subdivision in Section 14 which runs from the center point of Section 14 due south to the midpoint of the south section line of Section 14 (96th Avenue). This is needed to drill a boring and install a permanent cluster of three monitor wells at or near the tentative site which is about 2,600 ft east of the west line and 800 ft north of the south line of Section 14. This site is necessary to characterize the geology, hydrology, and possible contamination of the alluvium and Denver sandstones downgradient of the NBCS.

Site E-40 is offpost located on private property denoted by tax record number 1721-14-0-04-020 in the SW/4, SE/4 of Section 14, approximately 2,000 ft west of the east line and 1,300 ft north of the south line. This property is owned by:

Michael Bruce Collins
11515 East 96th Avenue
Commerce City, Colorado 80022
(303) 288-5969

Access to this property has been requested to install two Denver aquifer monitoring wells adjacent to an existing alluvial well (37305) after an initial boring is completed at the site. An easement of 20 ft along the eastern edge of the property or a satisfactory route chosen by the land owner has been requested. Future access to sample this well cluster will be needed on a periodic basis. This site is necessary to characterize the geology, hydrology, and possible contamination of the alluvium and Denver sandstones downgradient of the NBCS.

Site_E-41 is offpost located on private property denoted by tax record number 1721-14-0-04-019 which lies in the SE/4, SE/4 of Section 14 approximately 1,300 ft west of the east line and 600 ft north of the south line and is owned by:

Dorothy Lambert
11921 East 96th Avenue
Commerce City, Colorado 80022
(303) 287-2733

The access to this site is needed to drill a boring and install two Denver aquifer monitoring wells adjacent to an existing alluvial monitoring well (37304). The total permanent area of disturbance would be a 20 ft by 20 ft area adjacent to the fence. Future access to the cluster of wells would be needed for periodic ground water sampling. This land is currently up for sale by the owner. The boring and the installation of wells is required to assess the geology, hydrology, and possible contamination of Denver sandstones downgradient of the NBCS.

Site_E-42 is offpost on private property denoted by tax record number 1721-14-0-04-015 in the SE/4, SE/4 of Section 14, tentatively sited approximately 400 ft west of the east line and 660 ft north of the south line. The property is owned by:

Dorothy Lambert
11921 East 96th Avenue
Commerce City, Colorado 80022
(303) 287-2733

A 50-ft easement and corridor of access along the northern boundary of the property or any other suitable route of access as directed by the property owner is requested to gain access to the site to drill a test boring and install a cluster of three monitor wells. Total permanent disturbance will be an area around the well cluster of 20 ft by 20 ft. Future access on a periodic basis to sample the wells will be needed. Data from these installations will be used to evaluate the geology, hydrology, and water quality of the alluvium and Denver sandstones downgradient of the NBCS.

Site E-63 is an offpost site located on private property denoted by tax record 1721-00-0-00-030 in the SW/4 of Section 13 owned by:

Adams County Joint Venture
% Butler and Pierce
720 Kipling Street, Suite 201
Lakewood, Colorado 80215
(303) 232-3888

A 50-ft easement and corridor of access has been requested as part of the overall drilling program along the northern, eastern, and southwestern property lines of the property to drill several borings, and install monitoring wells. There will be three wells at Site E-63. Other sites on this property are part of Task 39. We will be requesting continued access along the north and southwest corridors for periodic sampling. The tentative location for this site is about 1,000 ft east of the west line and 1,000 ft north of the south line of Section 13. This site will be used to obtain geologic, hydrologic, and water quality data in the alluvium and Denver sandstones downgradient of the NBCS.

Tentative sites immediately north and northwest of the pilot portion of the system are listed below:

Site E-66 is tentatively proposed in the vicinity of alluvial well 23197 about 50 ft south of the north line (96th Avenue) and 2,200 ft west of the east line ("D" Street) in Section 23. Two Denver wells are proposed here to gather geologic, hydrologic, and chemical data.

Site E-67 is tentatively proposed near alluvial wells 23047 and 23048 about 50 ft south of the north line (96th Avenue) and 1,000 ft west of the east line ("D" Street) of Section 23. Two Denver wells would be completed there to collect geologic, hydrologic, and chemical data.

Additional sites to be considered would be northwest of the west end of the treatment system as well as several possible sites to fill in areas of data gaps between the NBCS and 96th Avenue where a high degree of detailed data might be needed. It has been found that some monitor wells in the Denver

Formation have been destroyed by maintenance operations (23172 and 23173). Several of these may have been to be replaced as part of this program.

3.1.1.3 Sites Upgradient of Barrier

At present, no specific sites for new ground water quality monitoring wells upgradient of the barrier have been chosen; however, it is anticipated that approximately five total sites will be needed. The specific location and type of wells will be outlined in a Letter Technical Plan. As with the downgradient wells, the upgradient wells will be chosen to supplement existing data from Tasks 4 and 25. In particular, siting will utilize the First Quarter Sampling Data from Task 25 (ESE, 1987, RIC#87014R24) and the data base established in Phase I of the Data Compilation portion of this study. Of particular interest upgradient is the extent and configuration of Denver Sand Units that have been defined at the North Boundary. Piezometric and water quality data from the sites will supplement existing data and permit a more precise evaluation of the extent to which these units may be acting as contaminant transport mediums. Data from these wells will also help determine whether potential point(s) of entry for contamination into Denver Sand Units are substantially upgradient or closer to the soil-bentonite barrier.

3.1.2 OFFPOST WELL REGISTRATION AND UTILITY COORDINATION

All new wells constructed offpost as part of Task 36 within the project area, will be registered with the State Engineer's Office. This practice assures that the offpost drilling program will remain in substantive compliance with applicable state laws and regulations.

ESE will be responsible for filing such registrations on behalf of the Army and for responding to reasonable and timely requests for samples, well logs, and other documentation by government agencies. The Corps of Engineers will be responsible for obtaining right-of-ways from other agencies or private landowners as appropriate. ESE will coordinate the registration activities for this task and other offpost tasks to avoid duplication of effort. ESE will also establish and maintain contact with all utility companies which may have service lines adjacent to the proposed drill sites.

3.2 BOREHOLE DRILLING AND MONITOR WELL INSTALLATION PROGRAM

Boreholes and/or monitor wells will be drilled using auger or rotary techniques according to conditions encountered at the site. Techniques and procedures associated with the drilling program including downhole geophysical surveys will be consistent with those outlined in Section 3.0 of the Task 1 Technical Plan (ESE, 1985, RIC#85127R07) and USATHAMA Geotechnical Requirements (1983).

3.2.1 INITIATION OF FIELD PROGRAM

Drilling equipment including drill rods, samplers, tools, and water tanks will be steam cleaned prior to arrival at RMA and washed with approved water before arrival at each boring or well site. Water to be used in drilling, grouting, or decontamination will be obtained at a source approved by the PMO-RMA. Only USATHAMA approved lubricants such as petroleum jelly will be used on the threads of downhole drilling equipment. Air usage will be fully documented with equipment descriptions, and oil filter specifications. Only USATHAMA approved air systems will be used.

3.2.2 SAMPLING

Continuous alluvial soil samples will be collected using rotary or hollow-stem auger sampling techniques. The continuous soil samples will be collected in polybutyrate tubes and transferred to a central logging facility. The soil samples will be logged and then stored in the polybutyrate tubes or one-pint wide-mouth jars.

Rotary core drilling methods will be used to collect 2 1/2-inch (in) diameter rock cores. Hollow-stem augers or conductor casing will be advanced into bedrock, sealed with bentonite, and then rinsed with approved water to minimize alluvial contamination. The 2 1/2-in rock core will be taken from a depth at least 5 ft below the water bearing unit which is to be screened. The rock core will be logged in detail, photographed, wrapped in plastic, and then stored in cardboard coreboxes. Pilot coreholes will be drilled and logged at all sites previous to well installation. These pilot coreholes will be abandoned in accordance with Section 3.4 of this Technical Plan.

3.2.3 WELL DRILLING AND INSTALLATION TECHNIQUES

Installation of monitor wells will begin within 12 consecutive hours of borehole completion for uncased or partially cased holes and within 60 consecutive hours in fully cased holes. Once installation has begun, no break in the installation process will be made until the well has been grouted and the protective casing installed. All materials used in well construction will be approved by USATHAMA and PMO-RMA prior to use.

Alluvial Wells--Alluvial wells will be drilled with 8 1/4-inch inside diameter (ID) hollow-stem augers following soil sample collection. The hollow-stem augers will be advanced 1 to 2 ft into bedrock. In general, wells will be screened from the bedrock contact to approximately 5 ft above the water table surface. Wells will be completed inside hollow-stem augers as shown in Figure 3.2-1. The details of the materials and methods to be used in well construction are described in Sections 3.2.4 through 3.2.8.

Bedrock Wells--In general, bedrock wells will be drilled using direct rotary methods. In instances when sloughing of alluvial material is a problem and precautions to prevent cross-contamination are not necessary (Figure 3.2-2a through Figure 3.2-2c), the alluvium can be drilled with hollow-stem augers. In instances where cross-contamination is possible the borehole will be reamed and conductor casing will be telescoped and grouted in place using Halliburton techniques. The specific type of installation will depend on the hydrogeology at the site and the aquifer to be monitored as shown in Figures 3.2-2d through 3.2.2g. Figure 3.2-3 is a schematic drawing of a typical cluster well installation. The well head completion will be the same as those specified for alluvial monitor wells (Figure 3.2-1). Pilot core holes will be drilled at all bedrock well sites to determine lithology and facilitate well installation.

3.2.4 WELL SCREENS, CASINGS, AND FITTINGS

Well screen will be commercially fabricated, high-flow, 20-slot (0.020-in) PVC having an ID of 4-in. The bottom of the screen will be fitted with a threaded PVC cap located within 6-in of the screen. The screen will extend throughout the water bearing unit and will be attached to schedule 40 PVC casing by a nonrestrictive threaded type joint. Alluvial wells will be

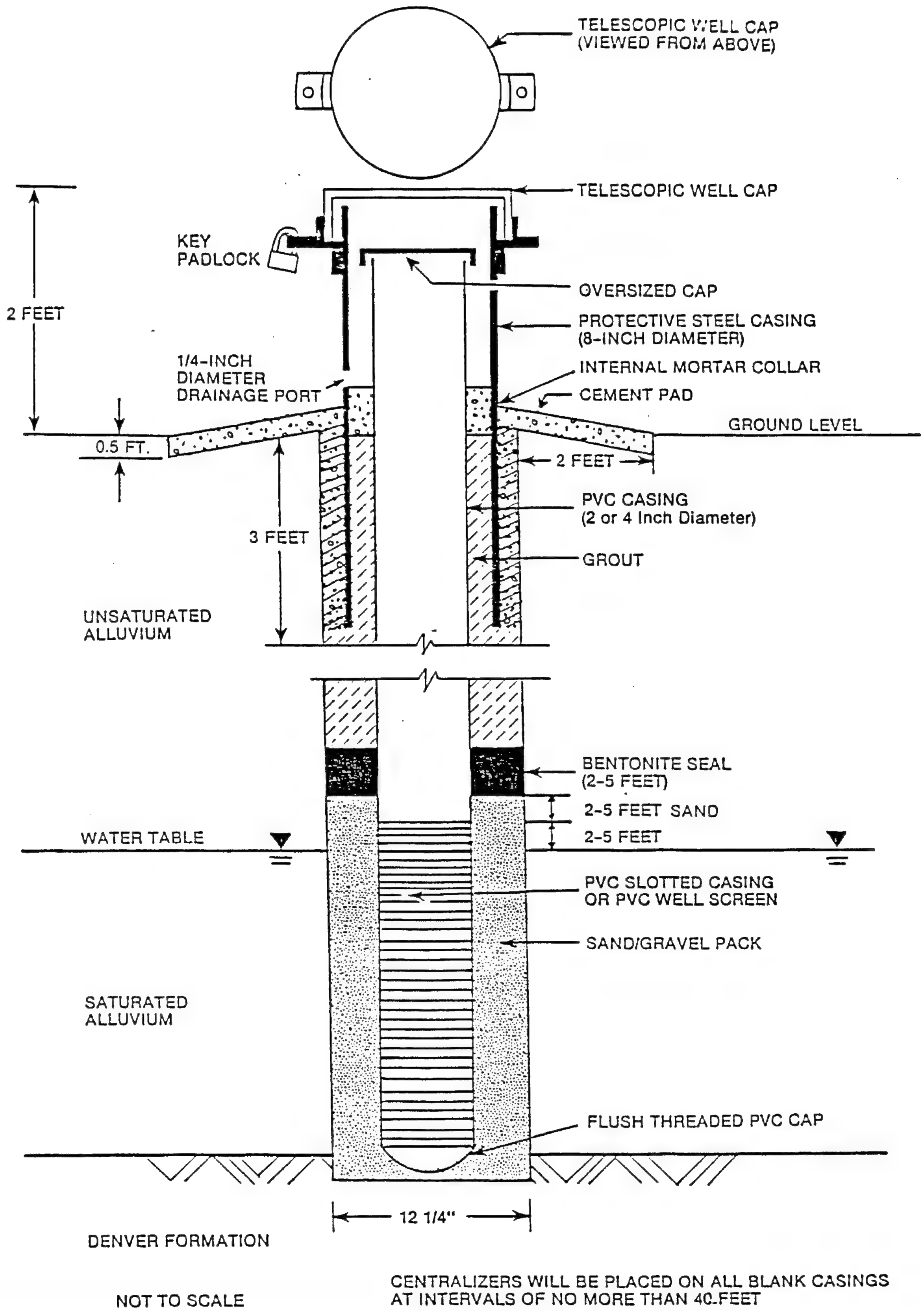


Figure 3.2-1
GENERALIZED AQUIFER MONITOR
WELL CONSTRUCTION

SOURCE: ESE, 1988

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

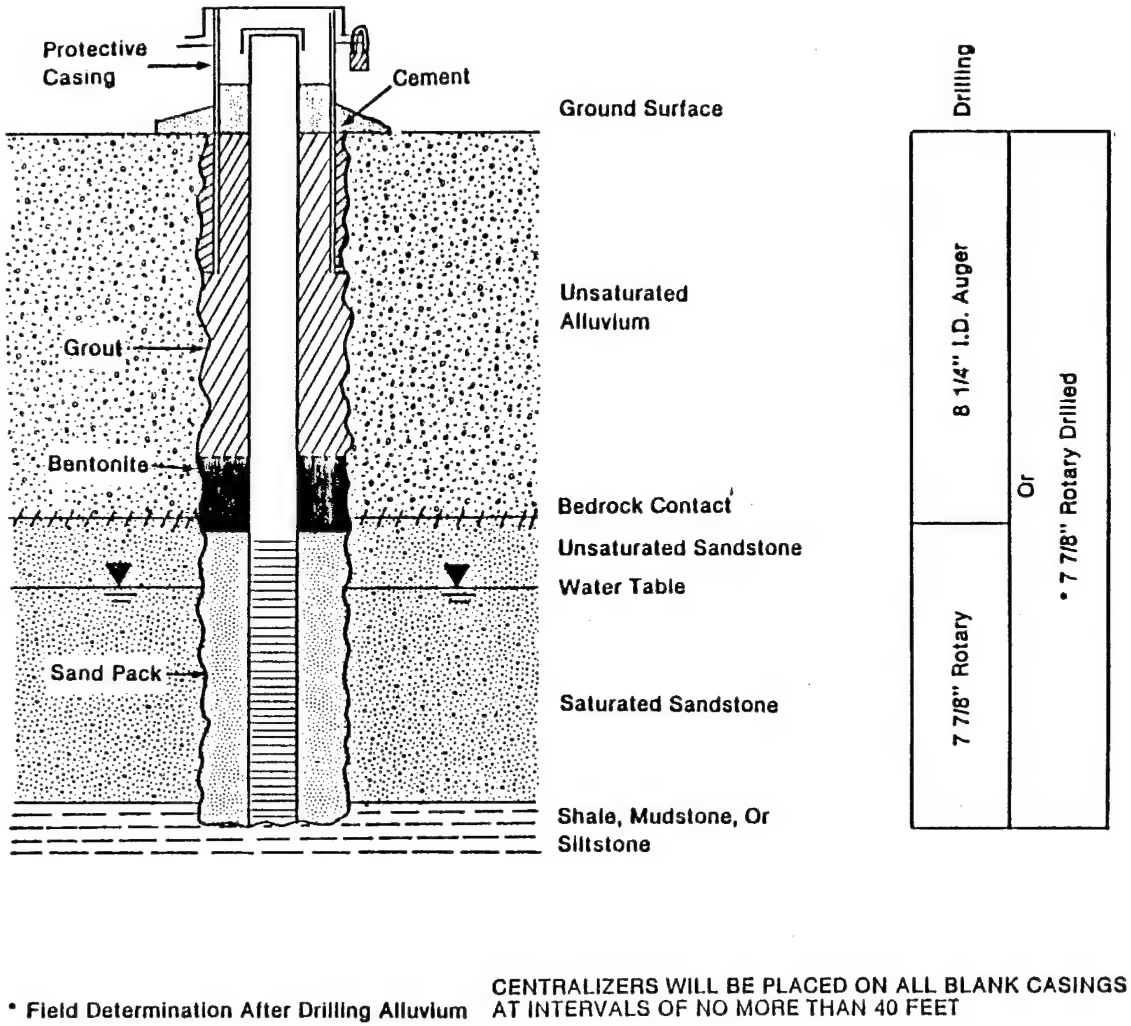


Figure 3.2-2a
GENERALIZED BEDROCK AQUIFER MONITOR WELL CONSTRUCTION (DENVER FM. WELL COMPLETED IN FIRST SANDSTONE, ALLUVIUM UNSATURATED, SANDSTONE AT THE ALLUVIAL-BEDROCK CONTACT, SANDSTONE PARTIALLY SATURATED)

SOURCE: ESE,1986

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

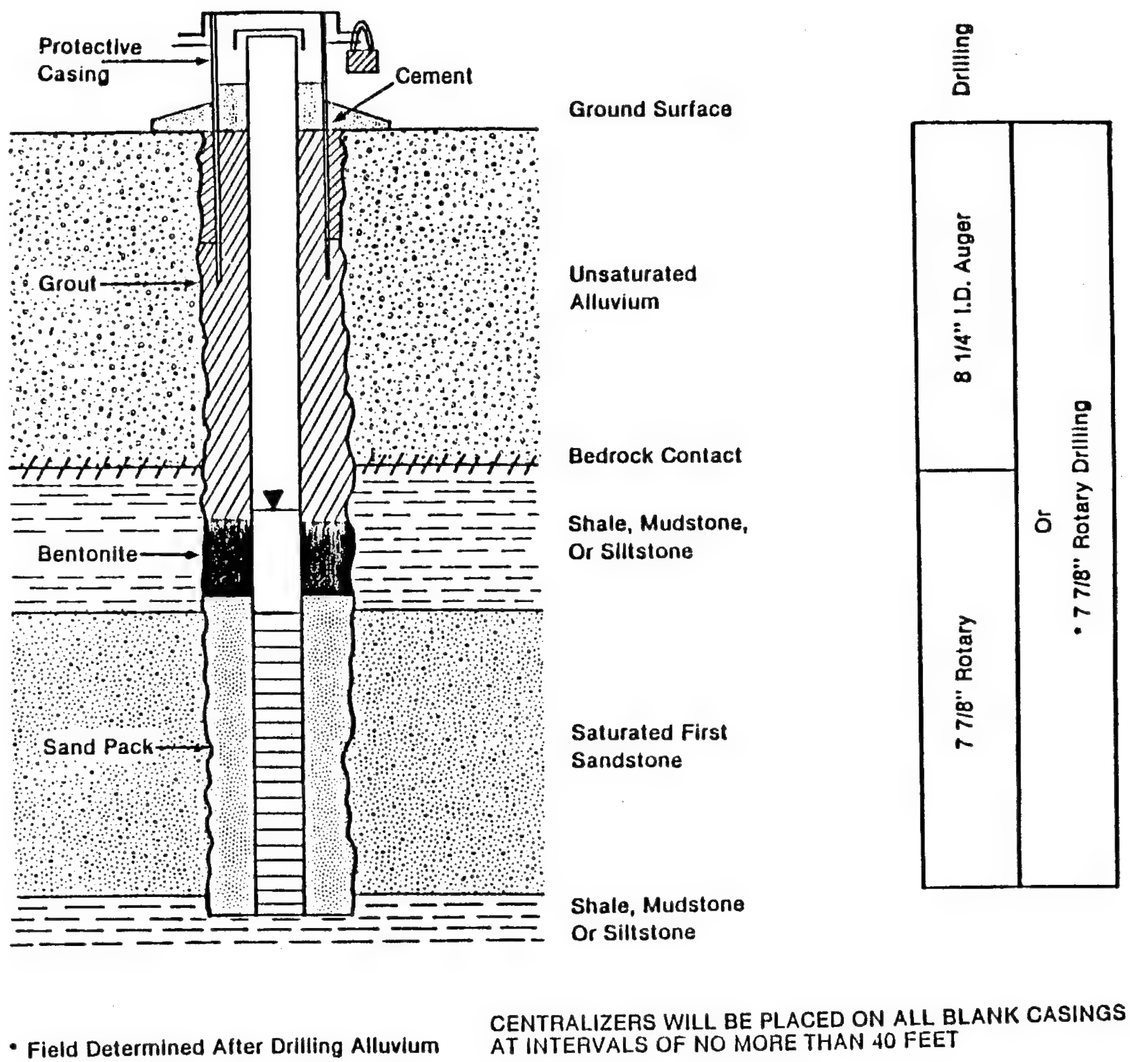


Figure 3.2-2b
GENERALIZED BEDROCK AQUIFER MONITOR WELL CONSTRUCTION (DENVER FM. WELL COMPLETED IN THE FIRST SANDSTONE, ALLUVIUM UNSATURATED, SHALE AT THE ALLUVIAL-BEDROCK CONTACT)

SOURCE: ESE, 1986

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

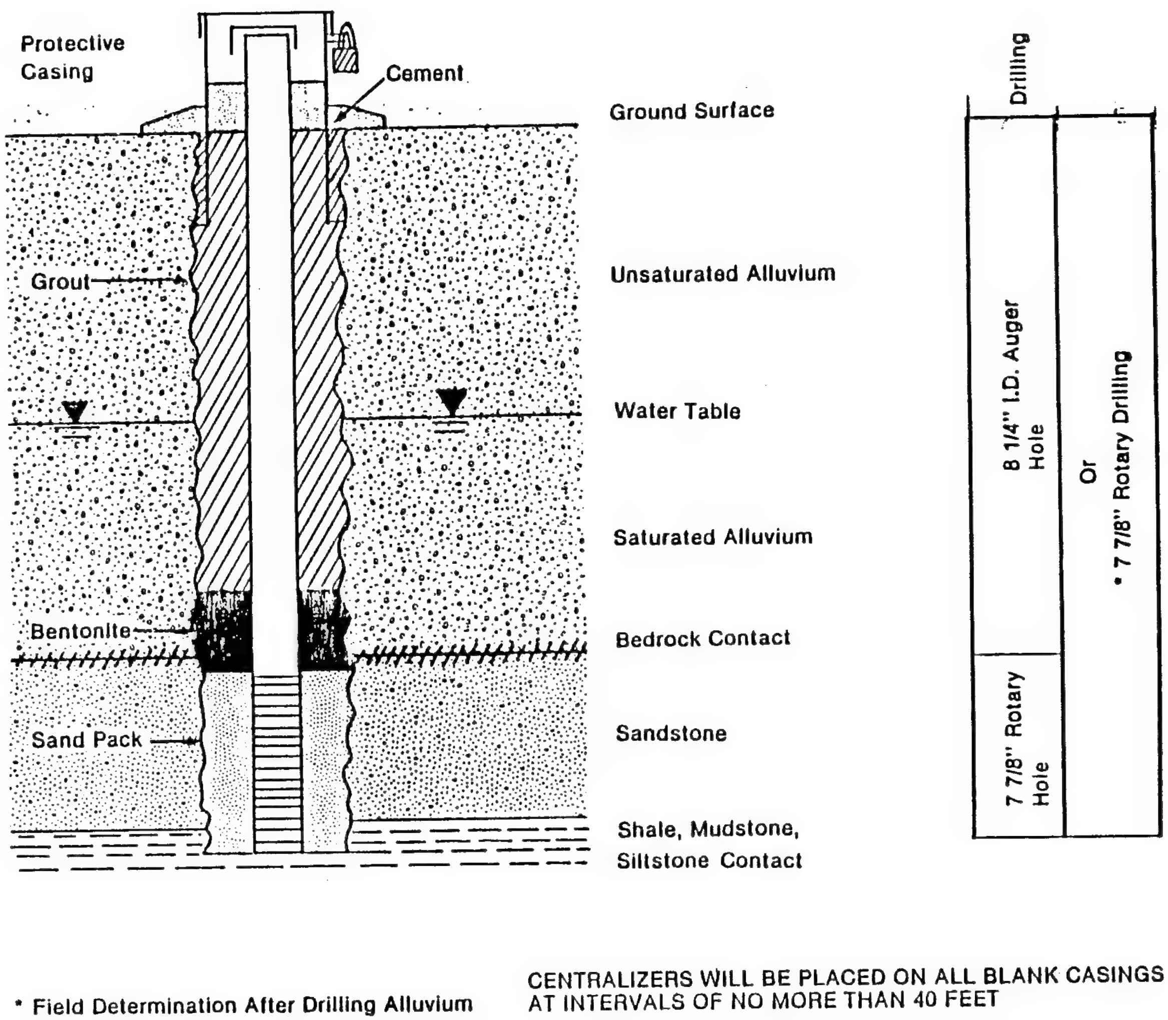
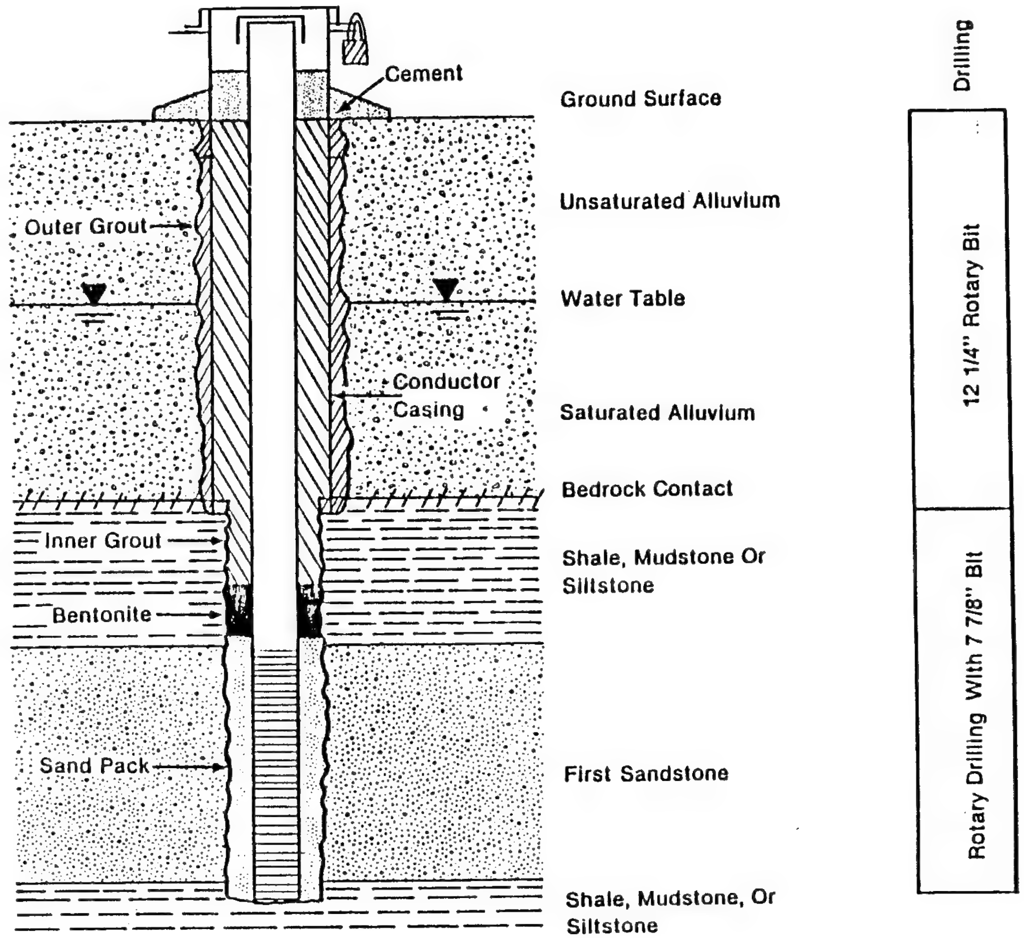


Figure 3.2-2c
GENERALIZED BEDROCK AQUIFER MONITOR WELL CONSTRUCTION (DENVER FM. WELL COMPLETED IN FIRST SANDSTONE, ALLUVIUM SATURATED, SANDSTONE AT THE ALLUVIAL-BEDROCK CONTACT)
SOURCE: ESE, 1986

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland



CENTRALIZERS WILL BE PLACED ON ALL BLANK CASINGS AT INTERVALS OF NO MORE THAN 40 FEET

Figure 3.2-2d
GENERALIZED BEDROCK AQUIFER MONITOR WELL CONSTRUCTION (DENVER FM. WELL COMPLETED IN FIRST SANDSTONE, ALLUVIUM SATURATED, SHALE AT THE ALLUVIAL-BEDROCK CONTACT)
SOURCE: ESE, 1986

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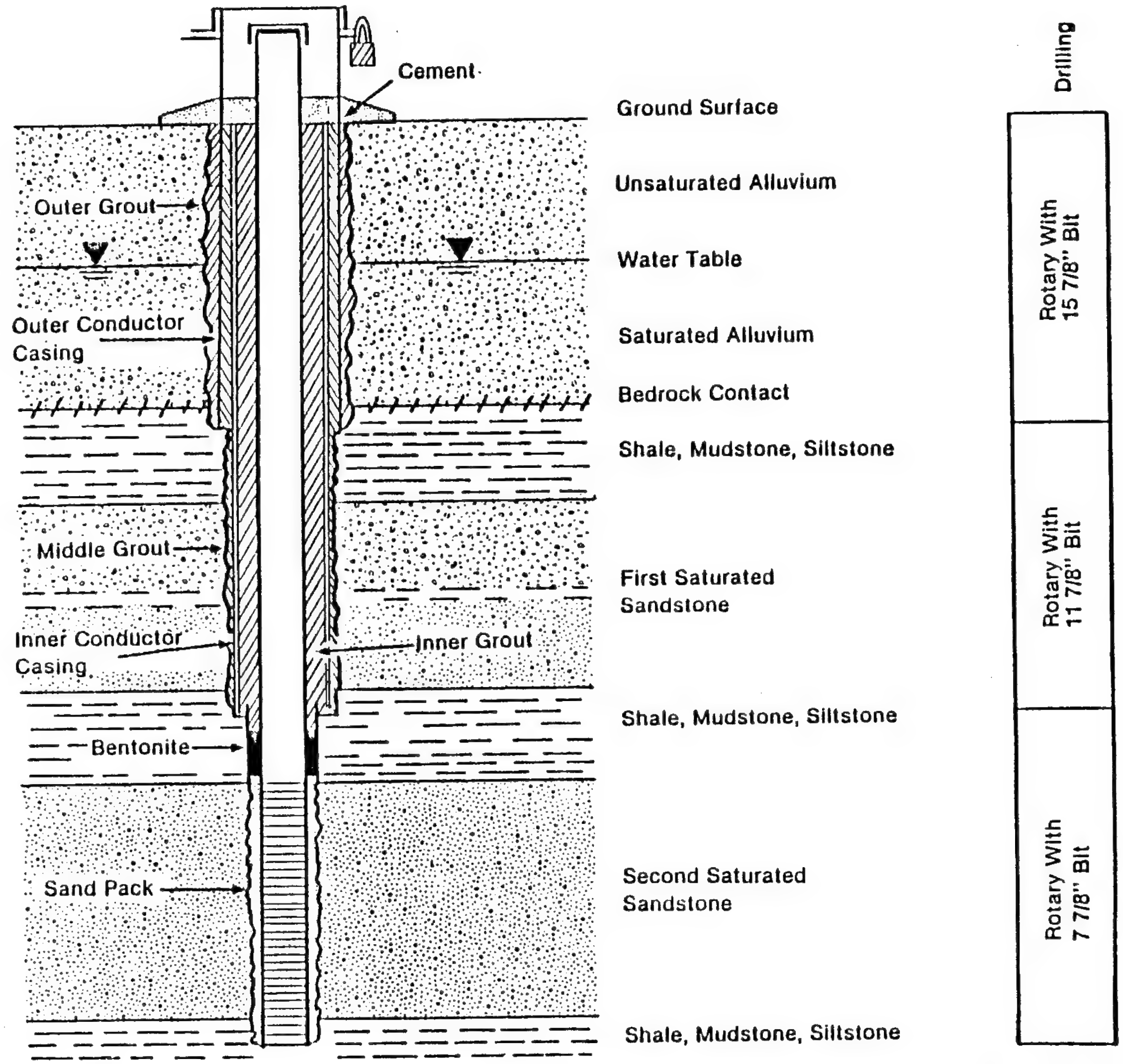

CENTRALIZERS WILL BE PLACED ON ALL BLANK CASINGS AT INTERVALS OF NO MORE THAN 40 FEET

Figure 3.2-2e
GENERALIZED BEDROCK AQUIFER MONITOR WELL CONSTRUCTION (DENVER FM. WELL COMPLETED IN SECOND SANDSTONE, ALLUVIUM SATURATED, SHALE AT THE ALLUVIAL-BEDROCK CONTACT)

SOURCE: ESE, 1986

Prepared for:
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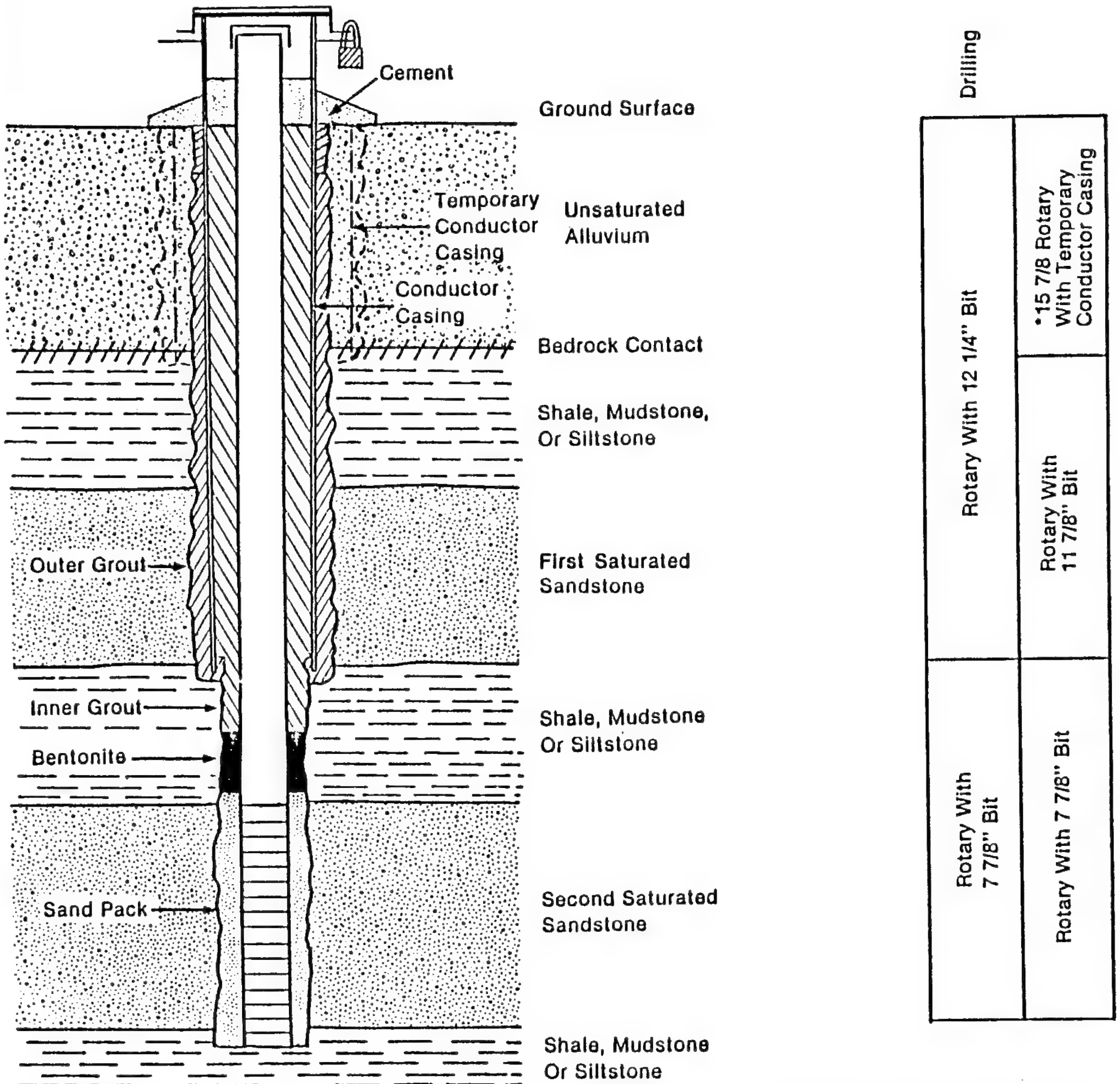

* Field Determination After Drilling Alluvium

CENTRALIZERS WILL BE PLACED ON ALL BLANK CASINGS AT INTERVALS OF NO MORE THAN 40 FEET

Figure 3.2-2f
GENERALIZED BEDROCK AQUIFER MONITOR WELL CONSTRUCTION (DENVER FM. WELL COMPLETED IN THE SECOND SANDSTONE, ALLUVIUM UNSATURATED, SHALE AT THE ALLUVIAL-BEDROCK CONTACT, FIRST AND SECOND SANDSTONE SATURATED)

SOURCE: ESE, 1986

Prepared for:
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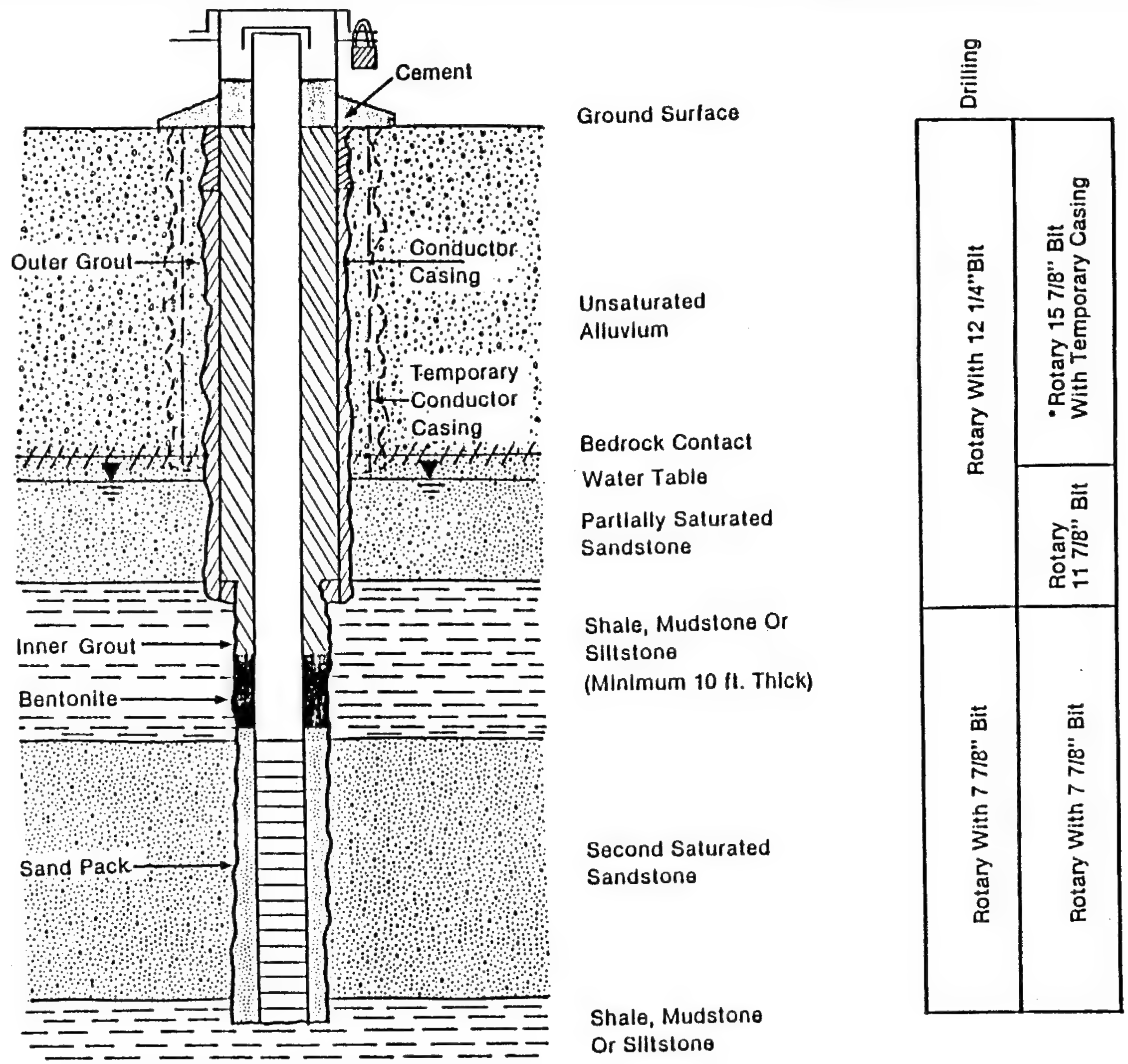
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland



• Field Determination After Drilling Alluvium

CENTRALIZERS WILL BE PLACED ON ALL BLANK CASINGS AT INTERVALS OF NO MORE THAN 40 FEET

Figure 3.2-2g
GENERALIZED BEDROCK AQUIFER MONITOR WELL CONSTRUCTION (DENVER FM. WELL COMPLETED IN THE SECOND SANDSTONE, ALLUVIUM UNSATURATED, SATURATED SANDSTONE AT THE ALLUVIAL-BEDROCK CONTACT)

SOURCE: ESE, 1986

Prepared for:
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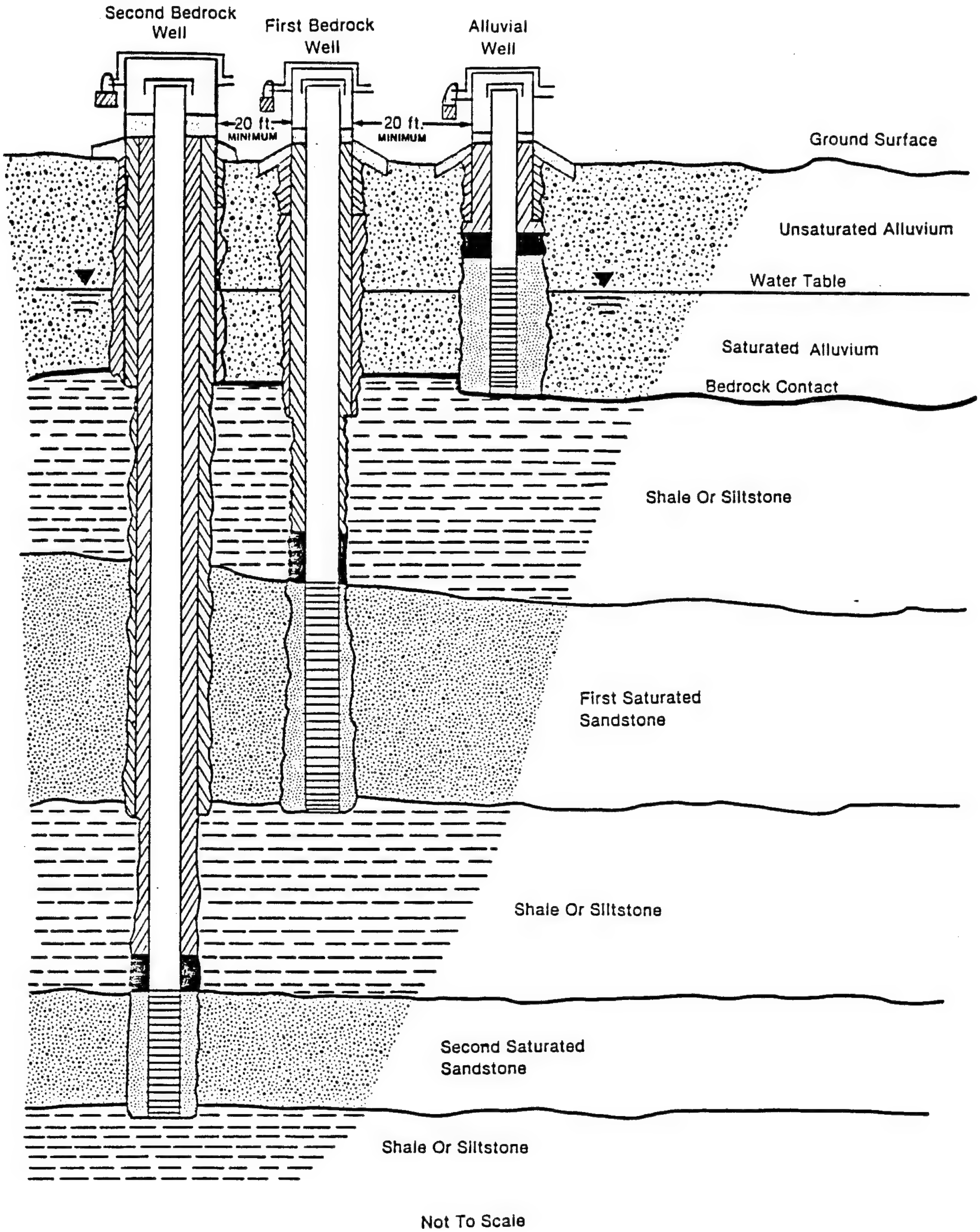
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland



CENTRALIZERS WILL BE PLACED ON ALL BLANK CASINGS AT INTERVALS OF NO MORE THAN 40 FEET

Figure 3.2-3
SCHEMATIC DRAWING OF A TYPICAL CLUSTER WELL INSTALLATION
SOURCE: ESE, 1986

Prepared for:
U.S. Army Program Manager's Office For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

screened 5 ft above the water table where conditions permit. Telescoped casing used to prevent cross-contamination between aquifers will be standard black iron pipe. Prior to installation all screens and casing materials will be decontaminated and stored in plastic. They will be clean and free from foreign matter (adhesive tape, labels, soil, grease, etc.) and will be washed with approved water. Casing tops will be fitted with oversized hand removable caps.

Stainless steel well centralizers will be attached by stainless steel clamps and will be used only on blank casing above the sand pack. Boreholes containing excessively thick or particulate-laden fluid that might preclude or hinder well installation may be purged with USATHAMA approved water.

3.2.5 SAND PACK

The annular space between the casing/screen assembly and the borehole will be filled with a sand pack to a depth of no less than 5 ft above the well screen. A 1-pint sample will be submitted to the PMO-RMA for approval prior to use on site. It is expected that the material used will be 8- to 12-mesh silica sand from Colorado Silica Sand, Inc. If water is needed to facilitate placement of the sand pack, a minimal amount of approved water will be used. The volume of this water will be recorded for subsequent removal during well development.

3.2.6 BENTONITE SEAL

A bentonite seal 5-ft thick will be placed above the sand pack except where shallow ground water table conditions prevent this. The thickness will be that measured immediately after placement, without allowance for swelling. The seal will be composed of commercially available bentonite pellets. This material will meet USATHAMA specifications and will be approved by PMO-RMA prior to use on the site. Bentonite seals will be placed as shown in Figure 3.2-1 through 3.2-3.

3.2.7 GROUT SEAL

Annular spaces in alluvial monitor wells will be grouted by pumping through a tremie-pipe placed at the bottom of the interval to be grouted or by gravity placement within the hollow-stem auger. The grout will be composed

of 20 parts cement to a minimum of 1 part bentonite, and a maximum of 12 gal of water per sack of cement. The annular space between conductor casings in Denver Formation monitor wells will be pressure grouted from the bottom of the casing using Haliburton type techniques. These materials will meet USATHAMA specifications and be approved by PMO-RMA prior to use on site. The grout seal will be inspected for settlement 24 hours after placement and grout will be added, if necessary, to the level of the ground surface.

3.2.8 PROTECTIVE CASING

A lockable protective casing will be set into the grout seal surrounding offpost wells. The casing will be constructed from 8-in-diameter steel pipe, 5 ft long, with a lid capable of being locked where telescoped casing is used on bedrock wells, the outer most pipe will extend above ground surface to form the protective casing. The casing will be cleaned of all foreign matter prior to use. It will extend into the grout at least 3.0 ft below the ground surface and will extend about 2.0 ft above the ground surface. The offpost wells will be padlocked at the time of the installation of the protective casing. After installation, the outside of the protective casing will be painted white, and the well identification will be painted black. All painting will be with a paintbrush and, not, with an aerosol can.

Onpost wells do not require casing. However, protective casing may be used at some onpost sites where there is considerable traffic and a substantial probability of damage.

Aggregate cement will be poured to a depth of about 0.5 ft above the ground surface in the annular space inside the protective well casing and outside the well casing a circular 4-ft-diameter pad 0.5-ft thick will be poured. A 0.25-in diameter drainage port will be drilled in the protective casing just above the level of the cement collar.

3.2.9 WELL DEVELOPMENT

Upon completion of the well installation, the monitoring wells will be developed at least two weeks prior to sampling. Well development will be conducted by means of either a submersible pump or a bottom discharge

bailer, with or without a surge block. A minimum of five times the volume of standing water in the well, sand pack, and annulus will be removed. If any water was added and lost during drilling or completing the well, five times this volume will be removed. The wells will be developed until the water is clear and as sediment-free as possible and any remaining sediment obstructs no more than 5 percent of the total screen length.

Measurements obtained and recorded will include static water levels before and after development, field pH, and conductivity measurements before, during, and after development. For each well, a 1-pint sample of the last water to be removed during development will be collected and retained. Appropriate forms and other pertinent data will be submitted to PMO-RMA or an authorized representative in accordance with USATHAMA Geotechnical Requirements (1983).

3.3 ALLUVIAL WATER LEVEL WELLS

Wells will be installed around the soil-bentonite barrier to provide a long-term monitoring system for water levels. These wells will be constructed of 2-in-inside diameter (ID) PVC 20-slot well screen and drilled using hollow-stem augering. Blank casing will be extended from the screened interval to 2 ft above the ground surface. A 4-in ID protective steel casing will be placed in a continuous grout seal and will extend above the top of the PVC casing.

3.4 ABANDONMENT

The abandonment of well sites will be required whenever and wherever the useful purpose of the site or installation is deemed unacceptable. The abandonment of wells will be approved by the Contracting Officer prior to any casing removal, sealing, or backfilling. Once removed, the borehole or monitor well to be abandoned shall be sealed by grouting from the bottom of the bore/well to ground surface. This shall be conducted by extending a grout pipe (tremie pipe) to the bottom of the bore/well (i.e., to the maximum depth drilled/bottom of well screen) and pumping grout through the grout pipe until undiluted grout flows from the bore/well at ground surface. Any open or ungrouted portion of the annular space between the well casing and borehole will also be grouted in the same manner. After grout

placement, the grout pipe, augers, and/or drill casing will be removed. When necessary, the grout placement and casing removal may be completed incrementally. This is done to maintain approximately 10 ft of grout within the casing and prevent collapse of the hole before grouting is complete.

After 24 hours, ESE will check the abandoned site for grout settlement. That day, any settlement depression shall be filled with grout and rechecked 24 hours later. This process shall be repeated until firm grout remains at ground surface.

3.5 DISPOSAL OF DRILLING REFUSE

Drilling, installation, development, and testing activities will generate borehole materials and fluids that may be contaminated. These materials will be containerized in 55-gal plastic drums and transported from the field to designated storage or disposal areas at RMA.

Task 32, "Waste Water Disposal", is the task that has the responsibility of handling all containerized wastes that are found to be contaminated. Each individual task has the responsibility of transporting contaminated wastes to a designated staging area and ensuring that all containers are properly labelled. The individual tasks also are responsible for disposing of uncontaminated ground water and soil in accordance with Task 32.

3.6 FIELD DOCUMENTATION

The Drill Site Geologist will be required to maintain a written record of daily activities. All records will be kept on prepared forms and will be signed and dated by the drill site geologist at the end of the day. This record lists all field personnel present during drilling activities.

The Drill Site Geologist will maintain a Record of Activities at the Drill Site (Figure 3.2-4) on which a time record of all drill site activities will be kept. The drill site geologists will also prepare as necessary a Borehole Summary, Well Construction Summary, Soil/Core Sample Chain-of-Custody, Borehole or Well Abandonment Report, and a Drill Site Geologist Daily Report (Figures 3.2-5 through 3.2-9).

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ENGLEWOOD, COLORADO 80112 • 303/741-0639

RECORD OF ACTIVITIES AT DRILL SITE

Boring Number: ______________ Well Number ______________ Date: ______________

Location: ______________ Project Number: ______________

Drill Site Geologist: ______________

Drill Site Geologist ______________ Date ______________

Figure 3.2-4
RECORD OF ACTIVITIES AT DRILL SITE

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

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BOREHOLE SUMMARY LOG

Borehole ____________________ Well ____________________

Project Name and Location ____________________ Project Number __________

Drilling Company __________ Driller __________ Rig Number __________

Drilling Method(s) ____________________

____

Size(s) and type(s) of bit(s) ____________________

Borehole Diameter ____ in. ____ cm. ____ ft. ____ cm. to ____ ft. ____ cm.

____ in. ____ cm. ____ ft. ____ cm. to ____ ft. ____ cm.

Sampling Methods ____________________

Total Number Soil Sampling Tubes __________

Total Number Core Boxes __________

Number of Gallons Lost Drilling Fluid __________

Date/Time Started Drilling __________

Date/Time Completed Drilling __________

Total Borehold Depth __________ ft. __________ cm.

Depth to Bedrock __________ ft. __________ cm.

Depth to Water __________ ft. __________ cm.

Water Level Determined By? __________

Borehole Completed as Monitoring Well? __________

Date/Time Grouting Completed __________

Depth of Tremmie Pipe __________

Gallons of Grout __________

Materials Used __________

Comments ____________________

____

____

Wellsite Geologist ____________________ Date __________

Checked for Grout Settlement on __________ by __________

Amount of Grout Added ____________________

All Measurements from Ground Level

Reviewed by ____________________ Date __________

Drill Site Geologist ____________________ Date __________

Figure 3.2-5
BOREHOLE SUMMARY LOG

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

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ENGLEWOOD, COLORADO 80112 • 303/741-0639

WELL CONSTRUCTION SUMMARY

Borehole ______________ Well ______________

Project Name and Location ______________ Project Number ______________

Drilling Company ______________ Driller ______________ Rig Number ______________

Drilling Method(s) ______________

Borehole Diameter ____ in. ____ cm. ____ ft. ____ cm. to ____ ft. ____ cm.
____ in. ____ cm. ____ ft. ____ cm. to ____ ft. ____ cm.

Size(s) and types of Bit(s) ______________

Size and Type PVC ______________

Total Borehole Depth	____ ft.	____ cm.
Depth to Bedrock	____ ft.	____ cm.
Depth to Water	____ ft.	____ cm.
Water Level Determined By	______________	
Length Plain PVC (total)	____ ft.	____ cm.
Length of Screen	____ ft.	____ cm.
Total Length of Well Casing	____ ft.	____ cm.
PVC Stick Up	____ ft.	____ cm.
Depth to Bottom of Screen	____ ft.	____ cm.
Depth to Top of Screen	____ ft.	____ cm.
Depth to Top of Sand	____ ft.	____ cm.
Depth to Top of Bentonite	____ ft.	____ cm.

Sampling Method(s) ______________

Date/Time Start Drilling ______________

Date/Time Finish Drilling ______________

Date/Time Start Completion ______________

Date/Time Cement Protective Casing ______________

Materials Used ______________

Plain PVC ______________

Slotted PVC ______________

Bentonite Pellets ______________

Bentonite Granular ______________

Cement ______________

Sand ______________

Water added during completion ______________

Water added during drilling ______________

Total Gallons of water added ______________

Drill Site Geologist ______________ Date ______________

Date/Time/Personnel Internal Mortar, Cement Pad, and Weep Hole Installed ______________

Date/Time/Personnel Casing Painted ______________

Date/Time/Personnel Numbers Painted ______________

Materials Used ______________

Top of Protective Casing to Top of PVC	____ ft.	____ cm.
Top of Protective Casing to Weep Hole	____ ft.	____ cm.
Top of Protective Casing to Internal Mortar	____ ft.	____ cm.
Top of Protective Casing to Top ofCement Pad	____ ft.	____ cm.
Top of Protective Casing to Ground Level	____ ft.	____ cm.

COMMENT/NOTES

____

Reviewed By ______________ Date ______________

Drill Site Geologist ______________ Date ______________

Figure 3.2-6
WELL CONSTRUCTION SUMMARY

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

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ENGLEWOOD, COLORADO 80112 • 303/741-0639

SOIL/CORE SAMPLE SHEET

CHAIN OF CUSTODY

BORE: ______________

Core/Sample Interal (Ft.)	Recovery (Ft.)	Box/Sample Tube Number	Comments

Relinquished By:(Name/Company/Date/Time) Received By:(Name/Company/Date/Time)

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________

Figure 3.2-7
SOIL CORE SAMPLE SHEET

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

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BOREHOLE ____________

SHEET ________ OF ________

BOREHOLE OR WELL ABANDONMENT REPORT

BORING NUMBER: ________ ________ DATE ________

PROJECT NUMBER: ________ TASK NUMBER: ________

PROJECT DESCRIPTION: ________

BEGAN DRILLING: ________ ENDED DRILLING: ________

	DEPTHS	DATES MEASURED
Total Depth:	________	________
Sampled to:	________	________
To Water:	________	________
	________	________
	________	________
To Mud:	________	________
Caved Hole:	________ to ________	________
	________ to ________	

ITEMS LEFT IN THE HOLE

Description: ________ Depth: ________

GROUT BACKFILL

Initial Quantity: ________ Date: ________

Quantity Added: ________ Date: ________

________ Date: ________

REASON FOR ABANDONMENT: ________

Figure 3.2-8
BOREHOLE OR WELL ABANDONMENT REPORT

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DRILL SITE GEOLOGIST DAILY REPORT

Geologist:______________________________ Date:______________

Borehole/Well:__________________________ Task:______________

Drill Rig/Drill Crew:______________________________________

Daily Crew Mobilization:__________________ Move & Set Up:__________

Well Completion:________________________ Decon:______________

Down Time:____

____

Stand By:____

____

	Feet Sampled	Feet Recovered	% Recovery
Continuous Soil Sampling:			
Continuous Rock Core:			

Auger Drilling:__________________________ Rotary Drilling:__________

____

Corehole Reaming:_______________________ Materials Supplied By Driller:__________

____

Total Hours Drill Site Geologist:___________________________

Comments:____

____

____

____

____

____

Driller/Date:____

Drill Site Geologist/Date:___________________________________

Reviewed By/Date:____

Figure 3.2-9
DRILL SITE GEOLOGIST DAILY REPORT

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Aberdeen Proving Ground, Maryland

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DAILY ACTIVITY SUMMARY

Personnel________________ Date________________

Time Start__________ Time Stop__________ Total Hours__________

Borehole/Well	Task	Activity/Materials Used	Hours

Personnel	Date	Reviewed By	Date

Figure 3.2-10
DAILY ACTIVITY SUMMARY

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SHEET______OF______

Borehole:________________ Well Number:________________

Depth - Feet	Tube Number Tube Interval	Recovery	Sample Number	Sample Interval	Unified Soil Classification	SOILS LOG Description

Drill Site Geologist:________________ Date:__________

Reviewed By:________________ Date:__________

Figure 3.2-11
SOILS LOG

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

ESE, Inc. CORE LOG By ________ Date ________ BORE ________ Well(s) ________ Page ___ of ___

BOX no.	DEPTH	Rec. Int.	Weath.	Structure / Bedding		Hard-ness	Perm.		Mineralogy		Color	Texture / Grain Size	Lith. Char.	Lith. Class	Description / Comments
			U S	Angle	Desc.	S H	1° L H	2° L H	Min.	Habit	M G	clay sd gr mm .01 1.0 100		Ft	CM (Scale 1" = ________ ft)

Reviewed By ____________ Date ________

ESE, Inc. BORE ________ WELL(S)

Figure 3.2-12
CORE LOG

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Aberdeen Proving Ground, Maryland

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SHEET ______ OF ______

WELL DEVELOPMENT DATA

Bore __________ Well __________

Project ____________________
Date(s) Developed ____________________
Personnel (Name/Company) ____________________
____
Rig Used ____________________
Pump (Type/Capacity) ____________________
Bailer (Type/Capacity) ____________________
Water Source ____________________
Measured Well Depth TOC (Initial) ______ ft.
(Final) ______ ft.

Project Number ____________________
Date Installed ____________________
Well Diameter (I.D.) ____________________ in.
Anulus Diameter ______ in. ______ ft. to ______ ft.
______ in. ______ ft. to ______ ft.
Screen Interval ______ ft. to ______ ft.
______ ft. to ______ ft.
Casing Height (Above G.L.) ____________________ ft.
Bottom of Screen (Below G.L.) ____________________ ft.

Water Level TOC/Date/Time (Initial) ____________________
(after 24 hrs.) ____________________

Feet of Water in Well ______ ft. x ______ gallons/foot = ______ gallons casing/anulus volume

Drilling Fluid Lost ____________________ gallons
Purge Water Lost ____________________ gallons
Added Water ____________________ gallons
Casing/Anulus Volume ____________________ gallons

One Purge Volume ____________________ gallons
Minimum Purge Volume ____________________ gallons
Total Purge Volume ____________________ gallons
Volume Measured By ____________________
Surge Technique ____________________

Calibration: pH Meter Used: ____________________
pH 7.00 = ______ at ______ °C, pH 10.00 = ______ at ______ °C
Conductance Meter Used: ____________________
Standard ______ umhos/cm at 25°, Reading ______ umhos/cm at ______ °C

Purge Volume	Time	Temp. °C	pH	Conductance at 25°C	Physical Characteristics (clarity, odor, sand content, color)
Initial					
Final					

Remarks: ____________________
____
____

Collected by ____________________
Signature Date

Checked by ____________________
Signature Date

Figure 3.2-13
WELL DEVELOPMENT DATA

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

All other field personnel will maintain a Daily Activities Summary (Figure 3.2-10). The geologist logging the soil and core samples will use the Soils Log and Core Log (Figures 3.2-11 and 3.2-12) to prepare detailed descriptions of samples following USATHAMA guidelines. The well development team will record development data on the Well Development Data Form (Figure 3.2-13).

3.7 HYDROGEOLOGIC DATA ACQUISITION

Hydrogeologic data will be required to determine the quantity, direction, and rate of ground water movement. This data will be needed to determine the hydrologic conditions at the NBCS, analyze the design, construction, and performance of the system, and recommend remedial actions for the system. Historical data has been collected from field and laboratory tests and will be evaluated for its adequacy in coverage and detail as part of the Data Compilation (Section 2.0). Where necessary, additional hydrogeologic data will be acquired using historically proven methods. All data from existing and new laboratory and field tests will be integrated to fully characterize the aquifers as needed for the system assessment.

3.7.1 AQUIFER TESTS

Pumping tests are the most accurate method of obtaining representative hydrogeologic data over large areas. In the past, these tests have been used successfully to characterize the hydrogeology near the NBCS (Vispi, 1978, RIC#81266R70; Black & Veatch, 1980, RIC#81266R25; May et al., 1980, RIC#81266R48).

Several pumping tests and slug tests have been performed on the alluvial aquifer in Sections 23 and 24 upgradient from the NBCS as well as on sandstones in the Denver Formation near the NBCS. Pumping tests have been proposed for approximately three wells offpost in Task 39 to estimate alluvial aquifer transmissivity and other hydrogeologic parameters. Where appropriate, this data will be applied to the area of interest in the NBCS. In the past, pumping tests have concentrated on the aquifers upgradient from the system. The suspected problems with recharge at the NBCS indicate some pumping or recharge tests may be required downgradient from the system to accurately characterize the transmissivity in recharge areas. Where

possible, hydraulic properties will be determined by correlating existingtest data to the different lithologic materials in the area.

Hydrogeologic data have historically been collected from the Denver Formation sandstones using both pumping tests and slug tests (Black & Veatch, 1980, RIC#81266R25; May et al, 1980, RIC#81266R48). Where appropriate, additional slug tests or pumping tests on the Denver sandstones will be considered if this data seems necessary for an overall assessment of flow through these units.

In order to characterize the local conditions within the NBCS, especially to see if hydraulic properties may have been altered because of the operation of the system, tests on existing production wells, such as well recovery tests for individual dewatering or recharge wells, can be performed as part of the operational evaluation of the system.

Data gathered from all of these tests will be analyzed using standard techniques. Values of the storage coefficient and transmissivity of aquifers can be calculated from test data by solving the differential equation applicable to the transient flow problem. Existing pumping test data will be reanalyzed where necessary to incorporate the most recent analytical techniques and enhance the reliability of transmissivity values.

The specific number, type, and locations of aquifer tests will depend on Phase I of the Data Compilation portion of this task. Based upon the findings of the review, specifics of the plans will be outlined in Letter Technical Plans and sent out for review.

Waste water from the pump tests will be handled as directed by PMO-RMA and Task 32. The alternative being considered at present is running the water through the NBCS.

3.7.2 LABORATORY TESTS

Permeability investigations are proposed for samples obtained from the drilling program to augment the field data. Selected samples, based on the variability of materials encountered during the drilling program will be

tested to obtain a range of permeability values for individual, characteristic borehole materials. These tests are proposed primarily for barrier samples and will include a determination of porosity.

The method suggested for determining hydraulic conductivity are laboratory permeability tests. Laboratory permeability tests may provide approximate data on aquifer transmissivity; however, this method utilizes a disturbed aquifer material sample, and the values obtained may not be representative of actual field conditions. These tests are generally conducted so that the permeability is measured in the vertical direction. This data does not usually represent the permeability in the primary direction of ground water flow, the horizontal direction, which is the hydraulic conductivity of primary importance in this ground water study. It is not anticipated that laboratory tests will be performed on aquier material samples.

3.7.3 WATER LEVEL MEASUREMENTS

The water levels measured under this task will be used to construct maps showing horizontal and vertical gradients, to help analyze the hydrogeologic response to system operation, and to assess the integrity of the barrier. Details of the methods to be used are outlined in Section 3.8.3.

3.8 SAMPLING PROGRAM

The sampling portion of the Geotechnical Program will address the acquisition of physical samples of several media on which various physical laboratory tests may be conducted. Samples collected as part of other tasks will be used where appropriate to minimize duplication by this task.

3.8.1 SAMPLING OF FRACTURED ROCK

Sampling of bedrock for fracture analysis may be proposed for the drilling program. Discussion of the acquisition of these samples has been addressed in Section 3.2.2. This sampling is considered necessary to assess the hydraulic conductivity of fractured Denver Formation below the soil-bentonite barrier. For this purpose angled coreholes are recommended to collect oriented core for fracture analysis because vertical holes may not intersect vertical fractures.

3.8.2 BARRIER SAMPLING

Physical samples of the barrier will be taken based on review of water levels and contaminant distributions around the barrier. For example, high downgradient contaminant concentrations or low head differences across the soil-bentonite barrier may indicate zones of relatively high permeability within the barrier. These indicators will be examined historically and supplemented with new data before a sampling program is initiated.

It is anticipated that vertical bores will be drilled using small diameter hollow-stem auger and sampled using a thin-walled Shelby tube. This procedure should give the sample size necessary to run physical laboratory tests and conduct chemical analyses while causing minimal disturbance to the barrier. All boreholes will be filled immediately with a compatible soil-bentonite mixture to seal the boreholes and minimize the potential increased flow through the wall.

3.8.3 WATER SAMPLING

A water sampling and water level monitoring program will be performed in the project area and will concentrate on newly completed wells. Methodology of sampling will conform to the established and approved procedures and protocol used in ongoing tasks utilizing the same field crews, equipment, schedules, and management teams. Rather than repeat the extensive protocol here, the reader is referred to the Technical Plan for Task 4 (ESE, 1986, RIC#86238R08) for the details of water sampling and monitoring. Sections 3.8.3.1 and 3.8.3.2 which follow briefly summarize sampling procedures and chain-of-custody and are excerpted from the Task 4 Technical Plan.

Two sets of water samples will be collected from an anticipated 35 wells. Each sample set will be collected over a short time span (1 to 2 weeks) to characterize contaminant migration at "instantaneous" points in time. (The long term evaluation of contaminant migration through the barrier is covered by Task 25). Two sample sets are needed for comparison purposes and to allow aquifer re-equilibration after new well installation.

Water level monitoring will be on a more frequent basis than sampling to discern fluctuations in the piezometric surfaces in response to the

operation of the system. Frequency will be determined from evaluation of the operation of the system. The number of water level data points will be much larger than water quality sample points.

3.8.3.1 Sampling Procedures

Ground water sampling methodology and techniques adhere to USATHAMA Geotechnical Requirements (1983) with respect to decontamination, collection, preservation, shipment, and chain-of-custody requirements. Further discussion of these aspects of sample collection is provided in the Task 4 Technical Plan (ESE, 1986, RIC#86238R08).

The following is a summary of the sampling procedures to be used in the investigative program:

- Sampling crews receive labeled sample kits from Field Team Coordinator;
- Record well number, date, pertinent information (e.g., weather and well conditions), station elevation, casing diameter, screened interval, and field equipment identification (manufacturer and ID number);
- Measure and record well stickup, depth to water, total well depth, HNU readings, and calculate well casing volume;
- Lower submersible pump to a few feet below the maximum drawdown or to the bottom of the well. If well is constricted above water level and pump will not pass, lower bailer to a few feet below water level. Record depth to pump or bailer;
- Pump or bail five casing volumes out of well. Measure and record time, pH, conductivity, and temperature after each well volume. Measure and record HNU readings by obtaining frequent background, well head, and discharge water values. If well is located within a known contamination plume or if HNU readings are obtained above background levels, discharge water will be collected in barrels. Otherwise water may be discharged on the ground at least 50 ft from the well head:
- Measure and record pumping rate, total pumping time, and total volume purged:
- Sample will be taken from the inline system, using care to verify

that flow rate is maintained during sampling to prevent volatile stripping;

- If the well is dewatered, remove pump. Sample within 24 hours using bottom filling and discharging stainless steel bailer. Measure pH conductivity, and temperature of sample obtained from bailer being used for sampling;
- Record time and measured values on sampling sheet, in field notebook, and on sample labels;
- Decant portion of water into sample bottles; cap bottles, agitate bottles, and discard water. Fill rinsed sample bottles directly from bailer. Record sample depth;
- Place bottles in ice chest;
- Complete chain-of-custody forms;
- Sign and date well sampling form; and
- Seal cooler and ship samples.

All pertinent data obtained during ground water sampling will be recorded on Field Sampling Data sheets and kept in a bound field notebook. The information recorded for each well sampled includes:

- Well number;
- Date and time (24-hour system);
- Pertinent observations (e.g., weather, well condition);
- Station elevation;
- Well stickup;
- Static water level and well depth;
- Casing diameter;
- Number of gallons per casing volume;
- Screened interval;
- HNU readings;
- Pump depth, measured pumping rates, total pumping time, and total volume of water removed:
- Characteristics of the water (color, odor, etc.):
- Measurements of pH, temperature, and conductivity:
- Identification of field equipment;
- Sampling description (number of bottles, sample fractions, sample depth);

- o Field notebook number; and
- o Signature of samplers and field team coordinator.

Records will be kept of all wells visited, including those found to be dry or constricted such that sampling was impossible. Dry wells include those wells with the water level below the bottom of the screened interval.

3.8.3.2 Sample Shipment/Chain-of-Custody

The ESE Site Geologist will serve as Sampling Team Leader and will supervise and assist in the sampling of all ground water and surface water sampling stations. Samples will be labelled, filtered, and preserved in the field. A log sheet will be filed and signed by the Site Geologist to serve as a check that all samples and operations are complete. Samples will be packed in styrofoam ice chests with sufficient ice to maintain less than 4 degrees centigrade (^{o}C) during transport to the laboratory. The ice will be double-bagged to prevent contact of the melt water with the samples. All samples will be checked for integrity and lid closure to prevent leakage.

The sampling logistics will occur as follows. The time elapsed between the first sample collection and initiation of processing in the laboratory will be approximately 24 to 30 hours, based on transportation schedules.

The Chemical Analysis Supervisor will be notified of sample shipment and estimated time of arrival. The Chemical Analysis Supervisor or a designate will receive the sample, verify the contents, and sign the log sheet. Samples are stored at ESE in a $4^{o}C$ refrigerator under the control of the Data Management Supervisor in the Sample Control Center. The procedures for sample fraction control during analysis are described in the Data Management Plan in Volume I of the Task 1 Technical Plan (ESE, 1985, RIC#85127R07).

Any sample which is leaking, any situations in which holding times are not met, or any other problems which may compromise the data, are noted at the time of receipt of the samples and reported to the Quality Assurance (QA) Supervisor for development of corrective action. The QA Supervisor verifies the chain-of-custody record of each sample set.

3.9 BARRIER TESTS

The testing of the physical condition of the soil-bentonite barrier is an option to be considered if other investigative means point to problems with the wall's integrity. Discussions of the relative merits and safety of the various tests is included in Section 8.3 Barrier Assessment. The following program is recommended based on the limited funds available for this project; however, one or more of the methods outlined in Section 8.3 may be considered if the scope-of-work for the assessment is modified at a later date.

3.9.1 LABORATORY TESTS

Physical sampling of the barrier will be directed by review of hydrological and contamination data as described in Section 3.8.2. Several laboratory tests are recommended for barrier samples. In addition to standard laboratory permeability tests and grain size analysis, various techniques may be utilized to determine the extent of any chemical and/or physical deterioration of the soil-bentonite mixture. X-ray diffraction coupled with chemical analysis could be used to characterize the composition of montmorillonite and to determine if mineralogical degradation has occurred through exposure to contaminants.

3.10 SURVEYING

Upon completing the installation of the final well, each well location, elevations of the ground surface, and the top of the well casing will be surveyed. Well locations will be accurate to within 3 ft using State Plane coordinates. Elevations will be surveyed to within 0.1 ft using the National Geodetic Vertical Datum of 1929.

Well identification numbers, map coordinates, and elevations will be recorded in a field log book and submitted to USATHAMA. A metal tag stamped with these data will be permanently attached to each protective casing.

4.0 CHEMICAL ANALYSIS

The objective of the analytical program is to provide PMO-RMA with reliable, statistically supportable, and legally defensible chemical data regarding type and level of ground water contamination in the area of the NBCS. To achieve this goal a schedule of the analytes previously detected near the boundary systems has been chosen. This analyte schedule was based on the contaminant distribution data from Task 4 (ESE, 1986, RIC#86238R08) and the first quarter results from Task 25 (ESE, 1987, RIC#87014R24) which are the most recent ground water quality data. The schedule will include 6 organosulfur compounds, 6 volatile aromatics, 8 organochlorine pesticides, DBCP, DCPD, MIBK, DIMP, DMMP, 12 volatile organohalogen compounds and 4 inorganic parameters (Table 4.0-1). Up to four additional inorganic parameters may be proposed via a Letter Technical Plan to help assess possible communication between alluvial and bedrock aquifers. These analytes are also denoted in Table 4.0-1.

Table 4.0-1. Chemical Analysis - Task 36 (Page 1 of 2)

Analysis/Analytes	Hold Time	Level of Certification	Reference Methods	Certified Reporting Limit (µg/l)	Method
Organochlorine Pesticides		Quantitative	EPA 608		CAP-GC/ECD
Aldrin	Extract as quickly as possible (no more than 7 days). Analyze within 30 days of extraction.			0.088	
Endrin				0.063	
Dieldrin				0.054	
Isodrin				0.072	
Hexachlorocyclopentadiene				0.147	
p,p´-DDE				0.071	
p,p´-DDT				0.066	
Chlordane				0.152	
Volatile Organohalogens		Quantitative	EPA 601		PACK-GC/Hall
Chlorobenzene	14 days			1.4	
Chloroform	14 days			1.9	
Carbon Tetrachloride	14 days			1.7	
trans-1,2-Dichloroethylene	14 days			1.8	
Trichloroethylene (TCE)	14 days			1.3	
Tetrachloroethylene	14 days			2.8	
1,1 Dichloroethylene	14 days			1.8	
1,1 Dichloroethane	14 days			1.9	
1,2 Dichloroethane	14 days			2.1	
1,1,1 Trichloroethane	14 days			1.1	
1,1,2 Trichloroethane	14 days			1.6	
Methylene Chloride	14 days			2.5	
Organosulfur Compounds		Quantitative			PACK-GC/FPD-S
P-Chlorophenylmethylsulfone ($PCPMSO_2$)	Extract as quickly as possible (no more than 7 days.) Analyze within 30 days of extraction.			2.6	
P-Chlorophenylmethylsulfoxide (PCPMSO)				3.2	
P-Chlorophenylmethylsulfide (PCPMS)				1.0	
1,4-Dithiane				1.6	
1,4-Oxathiane				1.4	
Dimethyldisulfide (DMDS)				1.7	
Volatile Aromatics		Quantitative	EPA-602		CAP/Hall
Benzene	14 days			1.92	
Toluene	14 days			2.1	
Ethyl benzene	14 days			0.62	
m-xylene	14 days			1.04	
o,p-xylene	14 days			1.34	

Table 4.0-1. Chemical Analysis - Task 36 (Page 2 of 2)

Analysis/Analytes	Hold Time	Level of Certification	Reference Methods	Certified Reporting Limit (µg/1)	Method
DCPD/MIBK		Quantitative	EPA 608		CAP-GC/FID
Dicyclopentadiene	Extract as quickly as possible (no more than 7 days). Analyze extract within 30 days of extraction.			9.31	
Methylisobutylketone				12.9	
DIMP/DMMP		Quantitative	EPA 622		PACK-GC/FPD-P
Diisopropylmethylphosphonate	Extract as quickly as possible (no more than 7 days). Analyze within 30 of extraction.			15.2	
Dimethylmethylphosphonate				10.5	
DBCP		Quantitative			CAP-GC/ECD
Dibromochloropropane	14 days			0.13	
Inorganics		Quantitative			
Arsenic			*EPA 206.2	0.39	Graphite Furnace
Chloride	28 days		EPA 200	4,800	Inductively Coupled P
Fluoride			EPA 300	1,200	Ion Chromatograph
Sulfate				10,000	
* Additional (Optional) Inorganics		Quantitative			
Sodium	6 months		EPA 273.1	763	
Calcium			EPA 215.1	500	
Magnesium			EPA 242.1	500	AA-FLAME
Potassium			EPA 258.1	1,260	AA-FLAME

Source: ESE, 1988.

5.0 QUALITY ASSURANCE

Quality Assurance for Task 36 will be consistent with the Field/Laboratory QA Plan developed for Task 1 activities. The plan is project specific and describes procedures for controlling and monitoring sampling and analysis activities as required under Task 36. As designed, the Field/Laboratory QA Plan will ensure the production of valid and properly formatted documentation concerning the precision, accuracy, and sensitivity of each method used for USATHAMA sampling and analysis efforts. The plan is presented in Appendix A of the Task 1 Technical Plan (ESE, 1985, RIC#85127R07). Specific RMA QA/Quality Control (QC) requirements are detailed in Section 5.0 of the same documents.

All tasks assigned under Contract DAAK11-84-D-0016 for "Litigation Technical Support and Services--Rocky Mountain Arsenal" require compliance with the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) QA Program of April 1982. The current plan is based on and, in general, complies with this USATHAMA QA Program. Deviations from USATHAMA QA procedures, where they occur, have been approved by USATHAMA and are indicated as deviations in the text. Specific details and deviations from the general plan, if any, for a certain task or survey will be described in detail in the Task Sampling and Analysis Plan or test plans. This plan will be implemented by ESE and all subcontractors performing sampling and analytical services.

The specific objectives of the QA/QC plan are to describe in general detail the processes for controlling the validity of the data generated in the sampling and analysis efforts, the methods and criteria for detection of out-of-control situations, steps to be taken to provide timely corrective action, and how such actions will be reported and documented. The Project QA/QC Plan also supports the Data Management Plan by providing documentation of the limits of precision, accuracy, and sensitivity of all analytical systems generating data and by providing mechanisms for documentation of the validity of all reported data.

Some survey tasks may require the development and documentation of certain semiquantitative and quantitative analytical methods for all phases of the project. The analytical systems controls and data validation procedures described in the QA/QC plan will be employed to ensure valid, properly formatted data defining the precision, accuracy, and sensitivity of each method.

5.1 QA ORGANIZATION AND RESPONSIBILITIES

This QA/QC Plan functions according to the USATHAMA central-laboratory/ field-laboratory concept. ESE and its subcontractor laboratory MRI act as the field laboratories, which are monitored by the USATHAMA Central Laboratory QA Coordinator. The overall QA/QC organization is shown in Figure 5.1-1. The function of the plan and QA responsibilities of each of the project participants are outlined in the following subsections.

Figure 5.1-1 depicts the manner in which the Project QA Supervisor monitors the conduct of the sampling and analytical effort. The Project QA Supervisor is not directly subordinate to anyone responsible for sampling and analysis and reports only to the Project Director. The Project QA Supervisor oversees the performance of the QA/QC Coordinator in the ESE and MRI laboratories. The Project QA Supervisor and QA/QC Coordinators (Project QA Staff) monitor the chemical analysis effort in their respective laboratories to ensure compliance with USATHAMA QA requirements and those of the Project QA/QC Plan. The Project QA staff also audit and monitor field sampling activities.

Field Quality Control procedures for this task will be consistent with EPA and USATHAMA approved methodologies. A summary of these procedures for all trip blanks, rinseate blanks, field blanks, and duplicates are summarized in Table 5.1-1.

The general manner in which the QA/QC Plan functions in each laboratory in terms of data review and monitoring is shown in Figure 5.1-2. The analyst performs the analysis of samples and control samples and plots QC sample results on control charts. The data are then processed through the Data Management System, where automated QC checks are performed, and the data are

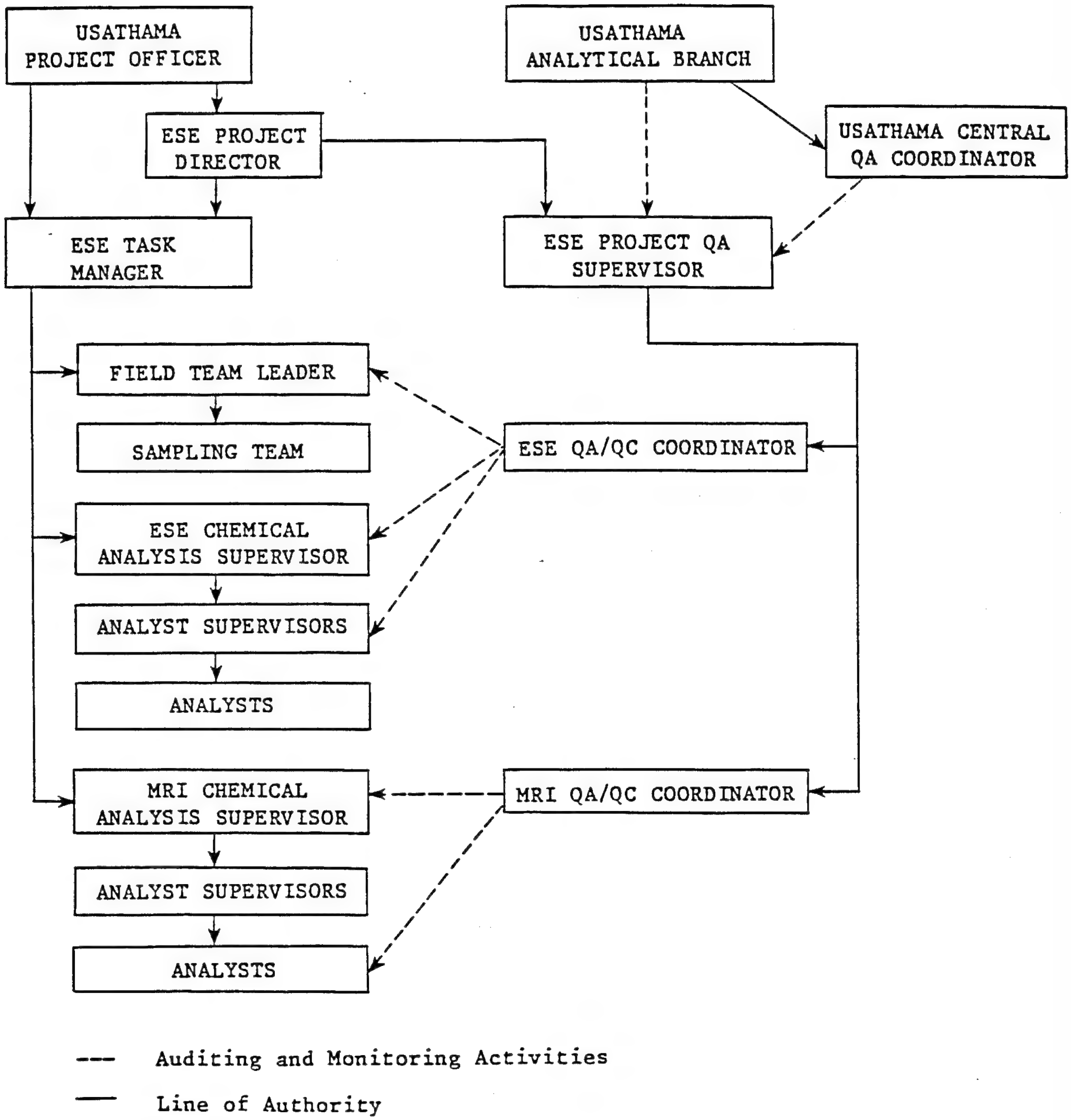

Figure 5.1-1
PROJECT QA/QC ORGANIZATION
SOURCE: ESE, 1985

Prepared for:
U.S. Army Program Manager's Office For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

Table 5.1-1. Field QA/QC Procedures

QA Sample Type	Analtyical Method*	Required Frequency	Preparation
Volatile Trip Blank	W8, Y8	1 paint can with 3 volatile septum vials per week, each week samples for GC analysis are collected.	Transport filled blank volatile septum vials to field, open paint can and return to laboratory with samples.
Rinseate Blank	S8, U8, T8, W8, Y8, X8, K8, R8, Q8	1 suite per week, each samples are submitted	Decontaminate bailer used to collect samples. Pour deionized water into cleaned bailer, then transfer to sample bottles. Perform while onsite. Not applicable if dedicated bailer is used.
Field Blank	S8, U8, T8, W8, Y8, X8, K8, Q8, R8	1 suite per week, each week samples are submitted	Pour organic free deionized water directly into sample bottles. Perform while onsite.
Duplicates	S8, U8, T8, W8, Y8, X8, K8, R8, Q8	1 suite per week, each week samples are submitted	Collect 2 suites of sample bottles while onsite.

* See Table 2.3-1 on Pages 2-14 through 2-16 in the Task 4 Report.

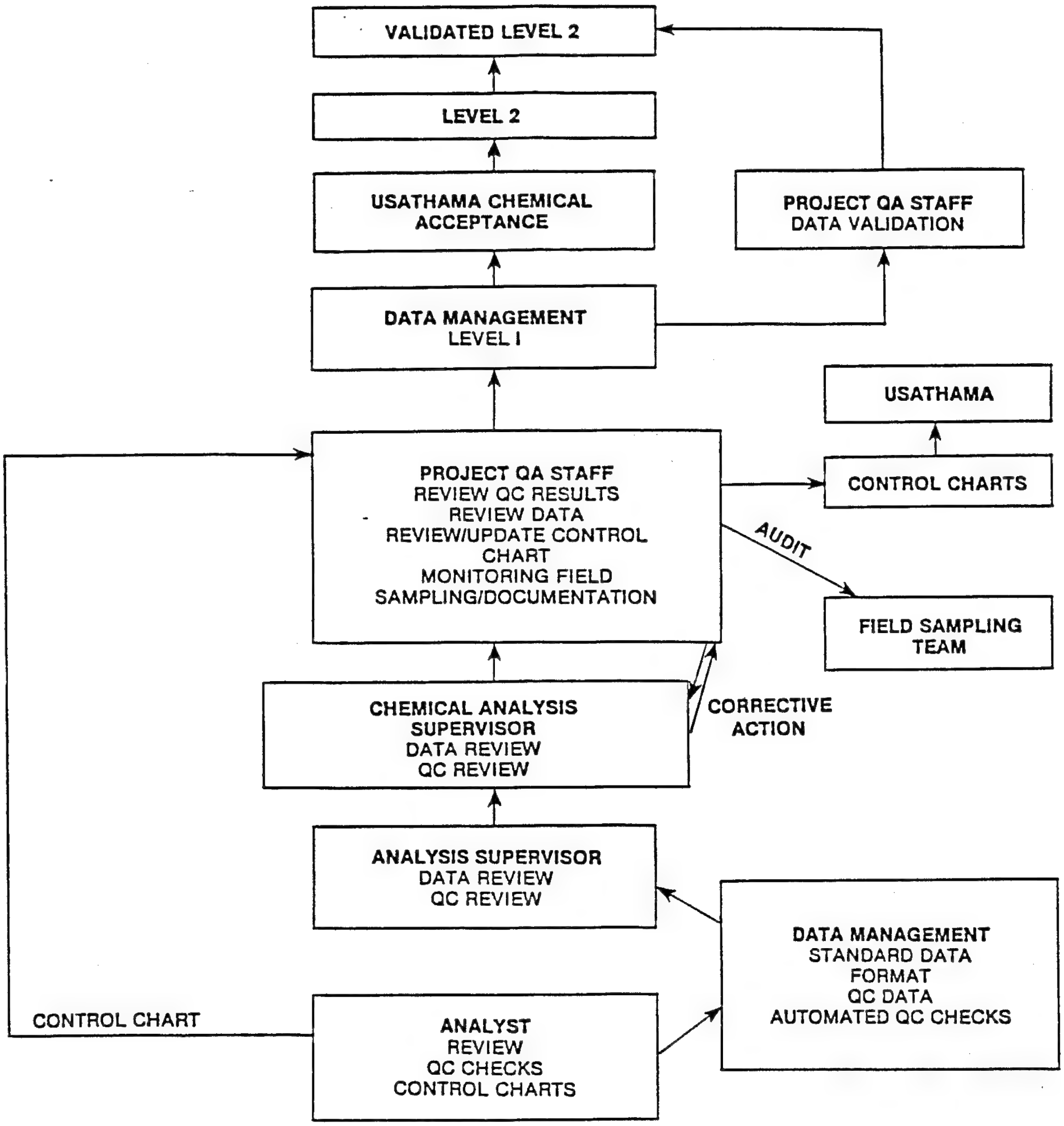

Figure 5.1-2
QA/QC PLAN FUNCTIONS
DATA FLOW AND QC CHECKS
SOURCE: ESE, 1985

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

presented in standard laboratory and USATHAMA format. The Analyst Supervisor then reviews and approves the data. The Task Chemical Analysis Supervisor then reviews and approves the data and QC results and submits the data batch to the Project QA staff for review. The Project QA staff review and data and monitors QC results and compliance with QA Plan requirements. The data may be returned to the Chemical Analysis Supervisor at this time for any necessary action to correct QC deficiencies.

The Project QA staff are also responsible for updating and reviewing control charts. After QA/QC review, the data batch is returned to the Data Management System for final processing, storage, and transmittal to the USATHAMA Installation Restoration Data Management System (IR-DMS). After entry into the IR-DMS at Level 1, the USATHAMA Chemical Acceptance Program is applied to the data. After the data batch passes the Chemical Acceptance program, the data may be elevated to Level 2 into the IR-DMS. After the data are in Level 1, the Project QA staff begin the process of validation of the chemical data. The validation process verifies the accuracy and transcription of a data subsample. When the validation process is completed, the Level 2 data are designated as validated in the IR-DMS system.

The Project QA Supervisor and QA/QC Coordinator monitor the field sampling effort by regulating the logging-in of samples, checking copies of field notebook entries and logsheets, and observing field sampling procedures and reporting any inconsistencies and/or omissions to the Field Team Leader. The QA Supervisor also monitors the QC and calibration data submitted to support field tests and analysis.

6.0 DATA MANAGEMENT PLAN

Data for Task 36 will be handled according to the Data Management Plan in Volume I of the Task 1 Technical Plan (ESE, 1985, RIC#85127R07), contract Number DAAK11-84-D-0016. As outlined in the plan, field data will be entered into the microcomputer network in the ESE Denver Office and transmitted to the ESE Gainesville Office via telephone modem. Field data will be transferred to IR-DMS, subjected to the Geotest data check routine, validated, and placed into Level 2. Ground water chemical sample number assignments, labels, and logsheets will be made in Denver and given to the sampling team. Samples shipped to laboratories will follow chain-of-custody procedures described in the Task 1 Technical Plan (ESE, 1985, RIC#85127R07). Data from laboratory analyses will be entered into the ESE Prime computer, incorporated with certification and field data, and formatted into files according to the IR-DMS User's Guide. After validation, chemical files will be sent to the Univac via telephone modem from ESE Gainesville, run through the data-checking routine, and elevated to Level 2.

7.0 SAFETY PROGRAM

The purpose of the safety program described in this section is to summarize the safety, accident, and fire protection standards and procedures and to outline standard operating procedures to ensure the safety of all ESE and subcontractor personnel performing Task 36 activities. Responsibilities, authorities, and reporting procedures designated for Task 36 are identical to those in Section 7.0 of the Task 1 Technical Plan (ESE, 1985, RIC#85127R07).

The program addresses all of the requirements of DI-A-5236B and fully complies with requirements of the Occupational Safety and Health Act (OSHA) and U.S. Army Material Development and Readiness Command (DARCOM) Regulation 385-100, Army Regulation (AR) 385-10, and Department of Army Pamphlet (DA-PAM) 385-1 for all activities to be conducted. The program also complies with the ESE Analytical Laboratory Safety Plan.

7.1 STANDARD PROCEDURES

7.1.1 WASTE CHARACTERISTICS

In the 43 year history of RMA, many extremely hazardous chemicals were manufactured, stored, or partially destroyed in demilitarization activities. Key compounds include GB and other nerve agents, H and L blister agents, munitions, organophosphorus pesticides and herbicides, phosgene, hydrazine, heavy metals, and chlorinated and unchlorinated organic solvents. High levels of organics have been detected in ground water in the area where Task 36 is concentrated. It is likely that some of these compounds may be encountered during the sampling and drilling activities to be carried out under Task 36. Detailed information on the chemical agents is given in the Agent Fact Sheet, SMCRM Form 357 (RMA, 1984) and Military Chemistry and Chemical Agents, TM 3-215 and AFM 355-7 (Departments of Army and Air Force, 1983). Copies of this information will be available at the Support Trailer at RMA.

7.1.2 GENERAL PROCEDURES

Task 36 activities include deep and shallow borings, well installation and development, and water sampling inside and outside RMA boundaries. These activities could expose field personnel to contaminated soils, rocks, and ground water. Because of this hazard, specific safety procedures are outlined later in this section. Communication requirements and buddy system procedures will remain the same as those detailed in the Task 1 (ESE, 1985, RIC#85127R07) and Task 4 (ESE, 1986, RIC#86238R08) Technical Plans.

7.1.3 DRILLING OPERATIONS

Soil borings and well installation will involve both auger and water rotary and core drilling techniques. General procedures to be followed when working on the drill rig are as follows:

- Daily inspection of all ropes, cables, bolts, and moving parts of the rig is mandatory;
- Hard hats will be worn at all times in the vicinity of the drilling rig;
- Goggles or safety glasses will be worn when operating power tools, sanding, grinding, or filing. Welders glasses or a mask will be worn in the vicinity of welding operations;
- No loose fitting clothing or free long hair is permitted near the rig;
- Hands will be kept out of the way of moving parts of the machinery when drilling is in progress;
- A first-aid kit and fire extinguisher will be available at all times;
- All crews will consist of at least two persons;
- There will be no smoking, eating, or drinking, except in the base administrative area or the support trailers. In no case will smoking materials or matches be disposed of onsite: and
- No drilling will occur during impending electrical storms or when rain or icing conditions create a hazard in working with equipment.

Because of the different hazards involved with each type of drilling, technique-specific safety procedures will be followed. The following sections describe the different procedures.

Auger and Water Rotary Drilling

Auger drilling will be used whenever possible due to the fact that material from the hole is easier to collect and contain, and remains at ground level. Well installation and deep borings for Task 36 will take place in areas where the soil has been found to be largely uncontaminated. Ground water, however, in much of this area is contaminated. Level D protection with steel toe and shank boots may be worn until drilling reaches a depth of 20 ft above the estimated water table depth. At this time, field personnel will don the following protective clothing and equipment:

- Saranex coated coveralls;
- Hard hat with face shield;
- Steel toe, steel shank boots;
- Latex rubber boot covers;
- Two pairs of chemical resistent gloves;
- Full-face, air purifying respirator with Scott 642-OV-H chemical cartridges (readily available);
- Fifteen-minute escape pack (readily available); and
- Safety glasses when face shield is not needed to protect the eyes.

The Site Geologist has responsibility for air monitoring and general safety during drilling. Monitoring, using the HNU or TIP photoionization detector, will take place at least every 5 ft of drilling until water is encountered. Once water is encountered, monitoring will be continuous until the total depth of the hole is reached.

When concentrations of organic vapors reach levels from above background to 5 parts per million (ppm) in the breathing zone, full face air purifying respirators will be worn. Field crew members will be required to don Level B protection where vapor levels are 5 ppm to 500 ppm in the breathing zone.

Air Rotary Drilling

Air rotary drilling techniques may be used where auger or water rotary drilling is not appropriate. Air rotary ejects soil, mud, and water from the hole with great force. Because of the much greater possibility of contacting contaminated materials during air rotary, safety procedures will differ from auger drilling. The following equipment will be worn as full Level C protection:

- o Hooded Saranex coated overall;
- o Full face, air purifying respirator;
- o Hard hat;
- o Steel toe, steel shank rubber boots;
- o Latex rubber boot covers;
- o Chemical resistant gloves; and
- o Fifteen minute escape pack.

Air monitoring will be extremely difficult because both the HNU and the TIP can become damaged when wet. There is also a danger of aspirating water or mud into the unit. While water and soil is being ejected from the borehole, no monitoring will take place in order to protect the instrument. During this time, full Level C protection will be worn. Also, in addition to the Saranex suit, drilling personnel will be required to wear a butyl rubber jacket over the Saranex suit to help repel the water. Other personnel working in the vicinity of the rig will be evaluated as to whether they will need a rubber jacket. These procedures will be followed whenever downhole material is being ejected from the boring.

Well Development, Water Sampling, Aquifer Testing, and Downhole Geophysical Logging

The greatest hazards from well development, well sampling, aquifer tests, and geophysics will be through skin contact with contaminated ground water and inhalation of volatile compounds being stripped from the water as it is being purged from the well. Field team members will don full Level C protection when approaching a well and removing its cap. The crew will then

monitor the breathing zone and downhole to determine the airborne hazards. Guidelines described for auger drilling will also apply to further respiratory protection.

When respirators are not worn, full face shields will be worn to protect the face from being splashed with contaminated water. Air monitoring will take place when each well casing volume is removed from the well or during pumping for aquifer tests. Detailed procedures for ground water sampling can be found in Section 7.0 of the Task 4 Technical Plan (ESE, 1986, RIC#86238R08).

7.1.4 HOTLINES

Hotlines will be established in a circular fashion around each deep boring and well. For auger and water rotary drilling, well development, and sampling, the hotline will be a 30-ft radius around the well. Air rotary drilling activities will require a 50-ft-radius hotline around the well. The required personal protection will be worn by all individuals within these hotlines.

If deep borings and well installation requires both auger and air rotary drilling, the hotline can be modified as drilling progresses but only in an increased fashion. In other words, if the hotline starts out at a 30-ft radius, it can be enlarged to 50 ft when air rotary drilling begins. However, a hotline cannot be made smaller on the same well. Once the hotline is 50 ft, it will remain that way for the remainder of the boring or well installation. The Site Geologist will have the responsibility of establishing and enforcing the hotline.

7.1.5 DECONTAMINATION PROCEDURES

Decontamination procedures will follow those procedures outlined in the Task 4 Technical Plan, Section 7.0. In summary these procedures are as follows:

- Vehicle seats and floorboards will be covered with plastic to aid in keeping them clean:

- All vehicles, equipment, and personnel entering the hot area will require decontamination;
- An initial decontamination will take place at the well site; and
- Field personnel will remove plastic from the inside of vehicles and proceed to the field wash trailer for showers.

7.2 CONTINGENCY PLANS

7.2.1 CHEMICAL AGENTS AND ORDNANCE

It is highly unlikely that chemical agents or ordnance will be encountered in the Task 36 study area. However, all crews will be supplied with M-8 detector paper as a precaution. The Site Geologists will be required to test formation water with this paper to check for agents in the water.

If chemical agent is detected, the emergency and evacuation procedures posted in the Command Post and field wash trailers, and detailed in the Task 1 Technical Plan (ESE, 1985, RIC#85127R07) will be followed.

7.2.2 EMERGENCY PROCEDURES AND SERVICES

In the event of an emergency onpost, (i.e., serious injury, fire, agent detection), the first point of contact will be the RMA Fire Department. For more detailed procedures for emergency situations refer to the Task 1 Technical Plan (ESE, 1985, RIC#85127R07). In the event of an offpost emergency, the first point of contact will be the Brighton Fire Department for the area north of 96th Avenue and east of Highway 2, and the Commerce City Fire Department for the area northwest of RMA.

8.0 SYSTEM ASSESSMENT/REMEDIAL ACTION

The objective of the response action assessment of the system components and geologic and hydrologic conditions is to determine the adequacy of the control system to intercept ground water contamination migrating in both the alluvial and Denver aquifers near the North Boundary. This response action assessment has been broken into three major areas of study to determine how much each may contribute to control system problems. The four components to be assessed are: the operation of the existing dewatering/recharge components, the flow of ground water that is by-passing the system, the carbon adsorption treatment system, and the physical condition of the bentonite slurry wall. The results of this integrated study will be used to make corrective recommendations to improve the system. The approach to be used in the treatment assessment are outlined in a Letter Technical Plan in Appendix A.

All assessment components will be investigated in close consultation with personnel from PMO-RMA, NBCS Operations, and Waterways Experiment Station (WES) while evaluating existing data, collecting new data, and evaluating response action alternatives. ESE will incorporate information obtained from the data review with data generated through the field programs to update background information. The Technical Report shall be prepared, discussing all technical work performed and assessments made, as described in and in accordance with DD Form 1423, A011. As a minimum, ESE will conduct monthly working sessions or Progress/Status Meetings with the PMO-RMA staff. ESE will present an oral briefing of drafts of the Technical Reports for the NBCS at RMA, Commerce City, Colorado.

8.1 ASSESSMENT OF DEWATERING AND RECHARGE COMPONENTS

More than any other factor, the inability of the NBCS to handle required flow rates at certain times has led to increased potential for flow of ground water through and around the control system. The objective of this portion of the study is to analyze the different components of the system, address operational and design problems associated with each, and develop conceptual solutions that can be implemented into cost-effective system alterations.

8.1.1 DEWATERING SYSTEM

It is evident from recent studies (Thompson et al., 1985, RIC#86078R01) that the treatment system flow has not consistently reflected the total flow of ground water approaching the barrier. Instead, the flow through the system reflects its ability to pump, treat, and recharge water at a rate that is often less than total ground water flow and is attributed most often to the lack of recharge capacity of the system.

The dewatering system may be responsible for part of the system's inability to handle required flows. Generally, the problems encountered with dewatering fall into two categories. First, the system has had mechanical problems which are due primarily to adverse weather conditions such as freezing and lightning strikes. Secondly, some of the dewatering wells are located in an unsuitable geologic environment. This includes wells which were placed in partially cemented gravelly sands and clay or clayey sand which have diminished dewatering capability.

The assessment of the dewatering system will focus on methods of improving reliability, means of rehabilitating wells that have performed poorly, and adding wells or other dewatering units. The goal of the assessment and subsequent recommendations will be to ensure that the modified system can reliably intercept all contaminated ground water approaching the North Boundary. Proper distribution and geologic placement of new dewatering units may be crucial to enhancing the existing system's long-term capability and reliability.

To achieve the goals of the study, an accurate depiction of the hydrogeologic media upgradient of the barrier is required. In this respect, existing data will be supplemented by ongoing programs to define problem areas and provide indications of suitable locations for new dewatering units. Inspection of existing well logs and testing of the dewatering system currently installed will provide additional data useful for design and placement of additional dewatering units.

The assessment of dewatering capability will also address modifications that will enhance the reliability of the system. This aspect of the study will emphasize mechanical problems that have been identified in the past and are likely to occur again based on historic trends. Conceptual design modifications, additional maintenance needs, and/or operational changes will be identified to improve efficiency and minimize down time.

8.1.2 RECHARGE SYSTEM

Several problems have been identified in the operation of the recharge system. The most notable of the problems is the insufficient number of recharge wells that appear to be necessary to recharge the water. Mechanical problems resulting from freezing and lightning strikes have also affected the recharge system. Even more important, the recharge system lacks sufficient recharge capability because of wells screened in areas of low permeability. In addition, carbon fines from the adsorbers in the treatment system have migrated through the post-filter to the recharge wells and further decreased recharge capability.

The assessment and recommendations for the recharge system will focus on means of maximizing existing recharge capabilities by implementation of additional maintenance programs, treatment system modifications to minimize the amount of carbon fines being discharged, and addition of new wells or other recharge alternatives to increase total recharge capability.

Evaluation of the siting of new recharge units will focus on placing the units in suitable geologic locations and minimizing effects on the regional ground water flow. Conceptual design of wells and other system components will specifically address those problems that have been identified in the past or are likely to occur based on historic trends and engineering judgement.

Modifications to the recharge system will ensure that it has the capability to recharge 125 percent of dewatering flows while accounting for expected

downtime and deterioration of wells. This margin of safety will provide for adequate recharge even during unexpected mechanical failures and/or periods when recharge units are not functioning at design levels.

Site investigations to be performed under this task will be utilized along with existing data to define a comprehensive view of the geology in the existing and proposed recharge areas. Assimilation of data will include inspection of existing well logs, evaluation of well performance records, and performance of pumping tests on existing wells. Analytical methods will subsequently be employed to find the optimal design, siting, and arrangement of additional recharge wells or other alternatives. The conceptual design will be optimized to handle design flows while minimizing effects to the regional ground water flow.

8.2 ASSESSMENT OF FLOW BY-PASSING SYSTEM

Regardless of the capability of the system components to fully handle all of the contaminated ground water flow encountered by the system, geohydrologic conditions appear to exist that allow flow around or under the barrier. These conditions may be intensified during system shutdown or at times when the system cannot keep pace with flow, so that these ground water flows could evade treatment by the system. The objective of this part of the assessment is to evaluate in detail the geologic and hydrologic conditions that are allowing or will allow contaminated ground water to by-pass the system. The results of this detailed hydrogeologic assessment will be used to suggest any cost effective design concept modifications along with operational modifications that may be implemented to improve system function and control these ground water flows.

8.2.1 FLOW AROUND SYSTEM

8.2.1.1 Geologic Investigations

The geologic and hydrologic conditions in the vicinity of the ends of the system will be compiled and compared to contaminant plumes in the alluvial and Denver aquifers to evaluate whether the lateral extent of the dewatering

and slurry wall components of the NBCS are sufficient to capture all contaminated flow. This investigation will utilize existing data and new data acquired by drilling and field investigations to compile detailed geologic cross sections and maps showing the configuration of alluvial and Denver Formation lithologies. Hydrologic and geochemical data will be compiled and then plotted onto the geologic interpretations and compared to system construction diagrams to see if the system is intercepting the full lateral extent of the plumes. This analysis would be used to assess various control options, such as the lateral expansion of alluvial and/or Denver aquifer dewatering wells if necessary to intercept the plumes.

8.2.2 FLOW IMMEDIATELY BELOW BARRIER WALL

The Thompson, et al. Performance Report (1985, RIC#86078R01) outlined a suspected zone of contaminant migration below the pilot portion of the system. This analysis will detail that zone as well as further investigate areas beneath the expansion portion of the system to verify its integrity.

8.2.2.1 Geologic Investigations

A detailed analysis of the Denver Formation at the base of the wall will be performed using compilation of old and new lithologic data. This will include an assessment of the ability of the fractured shale to conduct flow. It may be necessary to drill some angled core holes into the Denver Formation to collect oriented core for fracture analysis because vertical holes would not be likely to intersect vertical or high angle fractures. Vertical fractures are the type of fractures most likely to cause vertical and lateral flow. Data will be presented as geologic cross sections and maps showing lithology as well as structural data, such as fracture orientation and density.

8.2.2.2 In Situ Tests

Hydrologic data will be needed on the Denver Formation at the base of the barrier wall. May et al. (1980, RIC#81266R48) have pointed out that field and laboratory tests have shown the fractured shale locally has

permeabilities caused by fracture and joint interconnectivity comparable to the Denver Formation sandstones. Additional pump tests on wells completed in the shale zone below the wall will give data on local values of permeability. In addition, lab permeability tests run on samples collected from the core drilling will give pertinent information.

8.2.2.3 Analysis

Hydrologic, chemical, and geologic data will be plotted together with system construction details to give a three-dimensional analysis of the capability of the bedrock at the base of the wall to conduct ground water flow. Ground water flow rates will be estimated for this part of the system.

8.2.3 DEEP FLOW BELOW BARRIER WALL

Historic detection of contamination in Denver Formation wells as well as recent documentation of offpost contamination in areas where Denver sandstones are projected to subcrop dictates that substantial effort should be given to determining the three dimensional configuration of the sandstone bodies and their effect on the ground water hydrology. This analysis will overlap with the Task 39 program offpost and the Tasks 25 and 4 (future Task 44) programs onpost. Some part of this assessment will investigate whether the source of contamination in deeper Denver sandstones near the North Boundary is a result of local infiltration near the NBCS (possibly caused by the operation of the system itself) or whether contamination has migrated from a source upgradient. Access of contaminants to the deeper sandstones could be by natural pathways (i.e., contact between sandstones and contaminated alluvial flow or through fractured shale) or from man induced features.

8.2.3.1 Geologic Investigations

Geological data will be compiled onto cross sections and maps to determine the lateral continuity and extent of the Denver sandstones by evaluating geologic data from existing and new monitor wells and boreholes and domestic wells offpost. Hydrologic and chemical data will be plotted onto these

geologic bases to determine the total influence the Denver Formation has on contaminant transport in the area. This analysis will focus on determining the entry point(s) for contamination into these units (local vs. upgradient).

8.2.3.2 <u>In Situ Tests</u>

To fully characterize the hydrology of the Denver Formation sandstones, additional aquifer tests may be required. Pump tests and/or slug tests will be conducted where appropriate. A series of pump tests are proposed offpost in Task 39 to give data for the modeling program. This data will be utilized where useful to this study especially in the vicinity of the suspected discharge areas of the Denver sandstones into the alluvium.

8.2.3.3 <u>Leaking Wells</u>

Thompson, <u>et al</u>, (1985, RIC#86078R01) documented poor well construction for Dewatering Well 23342. At best, the poor construction gives a false detection of contamination in a deep Denver sandstone, and at worst, it could be a significant source for infiltration of pollutants from contaminated shallow sandstones into deeper units. Other existing wells will be evaluated for construction flaws, and appropriate response actions will be recommended.

8.3 <u>BARRIER WALL ASSESSMENT</u>

The initial function of the subsurface barrier at the North Boundary was twofold. First, the barrier was to assist in reducing the ground water flow in the system by increasing the drawdown on the upstream side and increasing the mounding effect on the downgradient side by preventing the recirculation of treated ground water. The original design intended that there would be no head difference across the wall. In this respect, the wall was to act as a divider between contaminated water approaching the upgradient side and the treated water on the downgradient side.

The second function of the trench was to act as a temporary "ground water dam" during downtime of the dewatering and/or recharge system. Due to the mechanical failure of some of the dewatering and recharge wells and the unsuitable geologic placement of certain recharge wells, the soil-bentonite barrier has consistently had to act as a ground water dam. This fact is significant for two major reasons as far as the integrity of the barrier itself is concerned. First, larger head differences across the wall caused by the "damming" effect would increase flow through the barrier. This would accentuate any existing zones of higher permeability within the wall. Secondly, the potential for exposure of the wall to possibly degrading contaminants is increased with larger head differences and thus greater flows. The extended period of the present "damming" condition implies that contaminant-barrier contact is more likely than previously surmised based on original design intentions.

Further contaminant contact with the barrier and hence, potential flow through the barrier, could be minimized by eliminating the head difference across the wall. Reducing this head difference will be the primary emphasis of this study. However, the efficiency of the wall in retarding flow remains important when considering the reduction of recirculation and the unexpected downtime of the hydraulic system when the barrier could still be required to act as a ground water dam.

8.3.1 IDENTIFICATION OF GENERAL PROBLEMS

Analysis of the barrier will focus on identifying factors which could lead to substantially increased hydraulic conductivity. Several physical factors must be considered when evaluating the long term integrity and effectiveness of soil-bentonite barriers when used to control pollution migration including the subsurface conditions surrounding the wall, the characteristics of the soil-bentonite mixture and the quality and quantity of filter cake formed along the trench walls. Examples of subsurface considerations that should be examined include the hydraulic gradient across the wall, in situ stresses and ground movement.

The characteristics of the soil-bentonite barrier will be dependent upon the type and relative quantity of bentonite and backfill, the quality of mixing and backfilling operations, and the effects of any contaminants. Effects from contaminants could be from utilizing contaminated water and/or backfill in the initial construction or subsequent effects from contaminated ground water.

8.3.2 IDENTIFICATION OF SPECIFIC PROBLEMS

An extensive review of data related to the NBCS will be undertaken to focus investigative efforts on those factors that pose potential problems. This review will include a detailed analysis of the barrier design and construction, an investigation of contaminants that may have come into contact with the soil-bentonite mixture, and an evaluation of the hydrogeologic media surrounding the wall.

This initial review will recognize the difference in design, construction, and extent of exposure to contaminants between the pilot barrier and the extension barrier. This differentiation is important in evaluating the applicability of various proposed investigations. For example, an investigation to determine the effect of certain contaminants might be applicable to the pilot barrier section but not the extension based on the historic location and movement of a contaminant and the differences in the age, construction methods, and consistency of the two barriers.

Analysis of the design and construction of the barrier will help to pinpoint potential problem areas within the wall. This analysis will include assessment of the soil-bentonite composition of the wall and general construction procedures and problems identified during installation. This encompasses documentation of any tests that were performed at the time of construction and inspections of the finished wall.

A review of contaminants that may have been and are presently near the barrier will be performed. Estimates of concentrations and length of

exposure will be determined. Emphasis will be on contaminants that have caused or are suspected of causing detrimental effects to soil-bentonite mixtures. Determination of which, if any, detrimental contaminants exist in the vicinity of the barrier will dictate the types and extent of tests to be performed.

A detailed evaluation of subsurface conditions surrounding the wall will provide valuable data on the effectiveness of the barrier. This investigation could help define areas of higher permeability and thus zones with greater potential for contaminant transport. The analysis will focus on historic and current water-levels on either side of the trench and the location and concentration of contaminants on the downgradient side.

8.3.3 MONITORING AND TESTING PROGRAM

8.3.3.1 Monitoring

Accurate water level data around the wall will be an integral part of determining zones of excessive flow through or around the barrier. Existing data should be supplemented by measuring water levels or pore pressures on both sides of the wall where existing wells are sparse.

Several methods are available to determine water levels. An open standpipe (or well point) is the simplest option but is generally considered a permanent installation. More temporary measures may be more appropriate due to the short-term nature of this assessment. However, the installation of a network of data points of high density will allow future detailed evaluations of the system, especially to monitor the effectiveness of remedial modifications that will be implemented from this study.

Evaluation of the contaminants downgradient of the barrier will provide invaluable information on the integrity of the wall. Historic location and concentrations of contaminants will be used to help pinpoint potential areas of concern. These efforts have been ongoing and should be augmented substantially by proposed new monitoring sites.

8.3.3.2 Testing

Based on review of construction records, historic contaminant plumes, and water level data, a testing program will be implemented to investigate zones of questionable integrity. Several testing options will be evaluated for their applicability to problems that are identified.

This first option consists of sampling the barrier and analyzing samples to determine hydraulic conductivity and whether the samples have undergone adverse physical changes due to contaminant interactions or adverse subsurface conditions. Hydraulic conductivity determinations will be made using laboratory tests performed at low gradients. In addition, x-ray diffraction and/or chemical analysis could be used to identify the percentage, composition, and crystallographic structure of bentonite. Grain size distribution tests can be used to document the amount of fines. Possible adverse chemical-soil- bentonite interactions that should be evaluated include dissolution, shrinkage, and flocculation.

Every effort will be taken to minimize the number of samples withdrawn from the wall due to the obvious disturbance and reduction in integrity that would result. Holes created by sampling operations will be grouted or filled with a compatible soil-bentonite mixture immediately afterward to minimize increased flow in these areas.

Several in situ tests may be of value in assessing the condition of the barrier. One option is the utilization of cone penetrometer tests to determine large nonhomogeneous zones within the trench. This determination could be made by comparing tip resistance and sleeve friction values at different depths within the trench. It is postulated that large zones of caving or poorly mixed backfill might be evident by substantially different resistance values. It is also probable that zones of coarse material might be evident by more rapid dissipation of excess pore pressure dissipation if pore pressures are monitored. This investigation would focus on areas

suspected of higher permeability based on monitoring and other preliminary investigations.

Cone penetrometer tests should result in minimal withdrawal of material from the barrier; however, such tests will increase pore pressures within the trench and could leave holes within the wall. These drawbacks and the lack of data that would be obtained indiate that sampling the barrier is a more appropriate method of investigation.

In situ slug type permeability tests are not recommended for this study due to the increased hydraulic pressures created. These tests have been known to cause hydraulic fracturing in fine-grained soils and may give erroneous values for low permeability materials.

A full scale test could be utilized to determine the effective permeability of the barrier and the media surrounding the barrier. This would be conducted by monitoring the rate at which the hydraulic gradient across the barrier changes during downtime of the dewatering/recharge system. The effective permeability could then be calculated using a falling head type analysis. This would be only approximate, however, because of the complexity of site conditions and the fact that the analysis is generally more suited to relatively permeable soils. The option will not be undertaken during this task because it might involve adversely altering system operation.

8.4 ASSESSMENT OF OVERALL SYSTEM INTEGRITY

The results of all of the individual system component assessments will be integrated and apportioned as to how each contributes to the control problems of the system to fully handle contaminated ground water flow in the area. In addition, an analysis of the interdependence of the components will be done so that the response actions that are recommended will be technically sound and cost effective. For example, if it is determined that deep sandstones are conducting contaminants offpost, and that the sources of

the contaminants into the sandstones are leaking wells, then by removing the leaking wells, the contribution of the deep Denver sandstones to the by-pass of the system will be negated. It would undoubtably be more logical to remediate leaking wells than to commit to building additional deep dewatering capacity and operating it for a long period of time to solve this hypothetical problem.

8.5 RECOMMENDATIONS

A detailed discussion of recommendations for improvement to the NBCS will be presented that takes into account the overall system integrity results discussed in Section 8.4. The recommendations will be categorized as to whether they should be considered for implementation as interim actions or evaluated as final response actions in the overall feasibility study. Recommendations for an interim action will be based upon the need to improve system operation before a final response action can be implemented.

9.0 MANAGEMENT AND ADMINISTRATION

ESE will devote sufficient project management, planning, consultant, supervisory, administrative, and clerical staff to ensure maintenance of a smoothly operating program, without impact on previous, ongoing, or subsequent tasks. A Management Plan has been prepared in accordance with DD Form 1423, A003, that includes a Resource Utilization Plan for this task, and Cost and Performance Reporting consistent with requirements of Task 1 (ESE, 1985, RIC#85127R07). Computer-to-computer communications will be maintained as implemented in Task 1 (ESE, 1985, RIC#85127R07). All simultaneous tasks having overlapping technical, geographic, and management needs will be coordinated to achieve maximum efficiency and output.

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APPENDIX A

LETTER TECHNICAL PLANS

February 13, 1987
Revised February 24, 1987
Project No. 86958

Letter Technical Plan

Re: Task 36, Rocky Mountain Arsenal North Boundary System Component Remedial Action Assessment; Soil-Bentonite Barrier Assessment

As outlined in the Draft Technical Plan and the Letter Technical Plan of January 2, 1987, Environmental Science and Engineering, Inc. (ESE) has recommended that existing alluvial water level monitoring wells be supplemented with additional open standpipes to adequately describe hydraulic conditions on both sides of the soil-bentonite barrier. There are two primary reasons for these installations. First, these monitoring points will provide invaluable data on the present effectiveness of the dewatering and recharge systems and their operations. Additional water level data will help further delineate problem areas and will be used in the conceptual design of additions and/or modifications to the present dewatering/recharge system. The proposed system will also provide reliable documentation of the effectiveness of proposed changes to correct adverse hydraulic conditions. The second reason for the system is to help delineate zones of questionable integrity within the soil-bentonite barrier. Specific areas to be sampled within the barrier will be guided by data obtained from the proposed water level measuring system.

The following is a list of existing wells that are close enough to the barrier and adequately constructed to give reliable measurements of water table elevations around the barrier:

23205	24178
23208	24179
23146	24180
24173	24181
24176	24182
24177	24183

It appears that all of these wells, except for 24176, are presently being monitored for water levels. These wells provide a substantial amount of information around the extension portion of the barrier. However, the areas of high contamination upgradient of the pilot barrier are not covered by existing wells. The proposed system has therefore been outlined to address the area around the pilot barrier. The approximate location and number of proposed sites are shown on the enclosed map along with the existing wells that will be utilized. The exact location and number of standpipes may be adjusted in the field to avoid construction difficulties and to provide data where it is most needed. Wells will be located as close to the barrier (approximately 25 feet) as feasible so that water level data will accurately reflect the hydrologic conditions immediately upgradient and downgradient of the barrier.

It is recommended that stainless steel pipe be driven where possible to minimize costs. However, where this is not feasible, sites will be drilled using hollow-stem augers or direct rotary methods. In this case, 1-inch (in) or 2-in (ID) 20 slot (0.020-in) PVC will be used as well screen. For all standpipes, the screened interval will be placed so that seasonal variations are taken into account along with possible water table changes from probable dewatering/recharge modifications.

For all wells, either blank PVC or stainless steel pipe casing will extend from the screened interval to 2 ft above the ground surface. 4-in-diameter steel pipe will be set into a 3 ft deep grout seal surrounding the well for protection. PVC caps will be used to seal the top of all wells. It is recommended that approximately three downgradient sites in the area of the pilot barrier be sampled using direct rotary or hollow-stem auger sampling techniques. These samples would be logged at a central logging facility. This data would be used to define the geology immediately downgradient of the barrier and would be used to help evaluate recharge additions that may be proposed under this task.

Prepared by,

Mark E. McClain

Mark E. McClain, P.E.
Task Manager

January 02, 1987
Revised February 23, 1987
Project No. 86958

Letter Technical Plan

Re: Task 36, Rocky Mountain Arsenal North Boundary System Component Remedial Action Assessment; Soil-Bentonite Barrier Assessment

Pursuant to the objectives identified for the Rocky Mountain Arsenal (RMA) North Boundary System Component Remedial Action Assessment, Environmental Science and Engineering, Inc. (ESE) has outlined a proposed program to assess the physical condition of the soil-bentonite barrier. The investigative program is designed to concentrate on areas within the barrier suspected of deterioration and/or relatively high permeability while minimizing overall disturbance. The rationale and details of the plan are described in this report. It is noted that the emphasis of this task will be placed on reducing hydaulic gradients across the wall which is the most effective means of minimizing flow through it.

The investigative program is developed to detect specific problems that may have occurred due to poor construction and/or adverse physical and chemical conditions. A brief review of the phenomena which may have adversely affected the integrity of the barrier and the likelihood of their occurrence, are briefly discussed below:

- Piping - Piping can be caused by excessive hydraulic gradients in conjunction with the use of improper backfill materials or construction procedures. Piping failures can be avoided by utilizing proper construction procedures, choosing suitable backfill materials and keeping hydraulic gradients across the barrier within design levels. The most important parameter for the backfill materials is the amount of fines (percent passing #200 sieve). Generally, a fines content of 20 to 25 percent is adequate to resist gradients of from 10 to 20 across the wall. The gradients at the North Boundary (NB) have reached a maximum of approximately 4. Therefore, if the required amount of fines were mixed in the original backfill and proper construction procedures used, piping should not be a concern for the barrier. A fines content of over 50 percent has been documented for the NB extension barrier. Documentation of the fines content for the pilot barrier has not been obtained by ESE. This information should be obtained from the investigative program if it can not be documented from other sources.

- Windows - "Windowing" in the barrier could occur by the placing of large quantities of unblended backfill or by sloughing of portions of the trench sides during excavation. Based on review of available construction records (U.S. Army Corps of Engineers, 1984) and conversations with RMA personnel, it appears that the original pilot and extension barriers were constructed from backfill materials that were adequately mixed with slurry before placement.

Based on this information and conversations with consultants involved with the barrier construction (Shallard, 1986), it does not appear likely that large and numerous zones of unblended material would exist within the barrier.

- Slurry Pockets - Slurry pockets can be formed during construction of soil-bentonite barriers if the slump of the backfill material is to great. This is caused when the backfill folds over itself and entraps the slurry. These pockets can remain in the wall and act like compressible layers with lower resistance to hydraulic gradients and chemical attack than the surrounding backfill (EPA, 1984). Based on construction records (U.S. Army Corps of Engineers, 1984) and conversations with consultants (Shallard, 1986), it seems that adequate measures were employed to minimize the possibility of entrapped slurry existing in the completed barrier.

- Chemical Effects - Ground water contaminants can substantially affect the physical/chemical properties of the bentonite and backfill material comprising the barrier (EPA, 1984). These interactions can lead to increased permeability of the barrier and in a worst case, piping or tunnelling failure of the wall. Numerous organic and inorganic contaminants can, through a variety of mechanisms, cause bentonite clay particles to shrink or swell. All of these mechanisms affect the quantity of water contained within the interspatial layers of the clay structure. In particular, inorganic salts can reduce the double layer of partially bound water surrounding the hydrated bentonite, thus reducing the effective size of the clay particles (D'Appolonia and Ryan, 1979). Organic contaminants can be sorbed into the internal surfaces of clay particles thus affecting the interlayer spacings (Anderson and Brown, 1981). These effects can lead to substantial increases in the permeability of the wall by increasing the amount of pore space in the backfill.

Of particular concern at the NB, are the high levels of calcium which have been found in the ground water near the barrier. Concentrations of calcium in excess of 800 ppm have been measured in this area. Prolonged exposure to ground water containing these high-levels of calcium may cause shrinkage and flocculation of the clay particles. These effects should be considered when determining what type of investigative program to employ.

In order to effectively evaluate the critical areas of the barrier, it is recommended that the investigations be directed by a thorough review of the construction history of the barrier and the contaminant concentrations and water levels around the barrier. In particular, the investigation should focus on determining whether the problems described above exist while minimizing disturbance to the barrier.

To achieve these goals it is recommended that additional water level monitoring points be installed on both sides of the barrier. For this purpose, well points could be installed at regular intervals and would

provide an accurate depiction of the hydraulic gradient across the wall. This information would be extremely beneficial in identifying zones of higher permeability within the wall, would not disturb the integrity of the barrier and would provide indications of the effectiveness of any modifications to the dewatering/recharge systems.

Utilizing water level and contaminant distribution data from around the barrier, a program of investigation will be initiated to assess the barrier's integrity in areas that are considered suspect. Two investigative techniques have been considered. The first is the electric cone penetrometer test (CPT). The CPT has been used effectively in recent years to classify subsurface materials based on measurements of cone bearing resistance, friction ratio and most recently, pore pressure. It is an attractive alternative for examining the condition of the barrier because of the minimal disturbance that it would cause.

The primary use of the CPT would be to delineate large zones of coarse material ("windows") within the wall. It is probable that the resistance values from the CPT could be read accurately enough to detect coarse grain zones less than a foot thick (Carter, R., 1986). However, based on review of the construction procedures, it appears that the mixing of backfill material and slurry was adequate to prevent the widespread occurrence of large unmixed zones.

Field studies performed by the U.S. Bureau of Reclamation (Engemoen, W. and Hensley, P., 1985) have been conducted to determine the effectiveness of the CPT in identifying slurry pockets. The results of these investigations showed that the CPT did not provide any reliable indications as to whether slurry pockets existed in the barrier studied. It is thus concluded that the CPT would be of limited use during the present investigation.

An alternative to the CPT is the withdrawal of samples from suspect zones for inspection and testing. The primary advantage of this technique is that it could be used to evaluate any effects from soil-bentonite and contaminant interactions and the other phenomena described above. Disturbance to the barrier can be minimized by immediate filling with compatible grouting materials.

Based on the data presented above, it is our opinion that sampling the barrier will be a more effective method of examining its integrity than performing cone penetration tests. The proposed sampling would be restricted to zones of questionable integrity as delineated by contaminant concentrations and water level data.

Permeability tests are recommended for selected samples to document representative hydraulic conductivity values for the barrier. X-ray diffraction tests are proposed for samples withdrawn from high contamination areas to assess any changes that may have occurred due to soil-bentonite and

contaminant interactions. All samples will be visually inspected for any abnormalities. Grain size distributions should be determined for the pilot barrier to document the percentage of fine-grained materials.

ESE proposes that this program would provide a representative and reliable indication of the condition of the soil-bentonite barrier.

Prepared by,

Mark E. McClain

Mark E. McClain, P.E.
Senior Associate Engineer

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November 26, 1986
Project No. 86946

Letter Technical Plan

Re: Tasks 25, 36, and 39-Offpost Monitoring Well Installation Program

Enclosed is information concerning Task 39, Offpost Remedial Investigation/Feasibility Study (RI/FS) at Rocky Mountain Arsenal (RMA). Environmental Science and Engineering, Inc. (ESE) has defined the objectives for the offpost monitoring well installation program and has prepared a tentative drilling sequence. Monitoring well locations are shown on the map which accompanied our August 14, 1986 Letter Technical Plan.

Also enclosed is a description of how the wells will be completed including various conditions for which conductive casing will be used to protect against cross-contamination between aquifers.

DRILLING PROGRAM OBJECTIVES AND TENTATIVE SEQUENCING

ESE has defined the objectives and estimated the drilling sequence for installation of offpost alluvial and Denver Formation wells. The programs are as follows:

ALLUVIAL WELLS

- o Objectives-Define pathway(s) for potential contaminant transport between the North Boundary of RMA and the 37344-Boller wells. It appears that alluvial ground water contaminated with RMA-specific compounds such as DIMP and DCPD is migrating north from RMA to the Boller well through the east half of Section 13. ESE will attempt to trace the plume southward from the 37344-Boller wells by installing alluvial monitor well(s) in the area of site E-53. Subsequently one or more monitor wells in the areas of E-45, E-46, E-47, and E-63 will be installed as appropriate;

  -Define the extent and concentration of alluvial ground water contamination downgradient of the Boller wells by installing one or more wells at or near site E-58;

  -Define extent of plume near the 37313 well by installing one or more wells in the area of E-50;

  -Establish or better define contaminant levels and pathways in alluvial ground water between the North Boundary of RMA and the area of well 37313. This will entail installation of alluvial wells at sites E-44, E-42, and E-39 as appropriate; and

  -Evaluate and define alluvial ground water contamination downgradient of the Northwest Boundary Containment System by installing one or more wells in the area of sites E-55 and E-60. The well siting would be based on water quality data from the Task 25 screening quarter and will be installed under Task 25.

o Tentative Sequencing-Wells will be installed at or near sites E-53 and E-58;
- Wells will be installed at or near sites E-39, E-42, and E-44;
- Newly installed wells will be sampled two weeks after completion and development;
- Based upon the results, additional wells may be installed near sites E-53 (E-54, E-64) and E-58 (E-52, E-57, E-59) and in the area of sites E-45 and E-47 (E-46);
- Based upon sample results from Task 25, one or more well will be installed near site E-63;
- Based upon sample results from Task 25, one or more wells will be installed near site E-55;
- Siting of some alluvial wells, particularly those in Section 13, will depend upon data from the soil/rock boring program; and
- The drilling sequence is highly variable, depending upon data evaluation from prior sampling, permits, and rights-of-way, and access.

DENVER FORMATION WELLS

o Objectives-Determine contaminant levels and pathways in certain sand horizons known to be contaminated upgradient of or peripheral to the North Boundary Containment System; and
- Evaluate contaminant levels in the upper part of the subcropping Denver Formation beneath areas of contaminated alluvium.

o Tentative Sequencing-Continuously cored borings will be drilled to determine the extent and geometry of Denver sand horizons that are contaminated onpost. The area of principal concern here extends from the North Boundary of RMA to First Creek. Bore holes at sites E-38, E-39, E-40, E-41, E-42, and E-63 will be drilled to depths of 100 to 150 feet (ft). An area of secondary concern for Denver Formation ground water contamination extends from north of First Creek to the area of the Boller wells. Cored borings in this area will be drilled to depths of 50 to 100 ft;
- When enough information is available from the boring program to outline the geology of the Denver Formation as it relates to contaminant transport, monitor wells will be installed in the key sand horizons that are contaminated onpost. At each site in the area between the North Boundary of RMA and First Creek, wells will most likely be installed in the upper two sand horizons of the Denver Formations. If, however, the second sand horizon on RMA is found by Task 25 sampling to be uncontaminated, then wells will only be installed

in the upper sand horizon;
- In the northern part of Sections 13 and 14, Denver wells will be installed only in the uppermost sand horizon below the first shale. These will be installed to evaluate the possibility of contaminant transport in Denver Formation sands;
- Surface geophysical techniques may be used to help site alluvial wells but only after general agreement as to efficiency of method and cost;
- Borehole geophysical techniques will be used to define stratigraphy in the Denver Formation. The logging suite will be chosen after discussion with EBASCO, R.L. Stollar and Associates, and Harding Lawson Associates; and
- The program will be dynamic and new data may require alteration to the plans. The alterations would be made only after discussion with PMO-RMA.

DENVER FORMATION WELL COMPLETION PROCEDURES

OBJECTIVES

The purpose of isolating overlying strata from sandstone aquifers in the Denver Formation north and northwest of RMA is to prevent introduction of overlying contamination and the downward migration of contamination during drilling and monitor well installation.

METHODS

Methods and materials will be on a well specific basis. Specific installation techniques are shown for the different conditions to be encountered as diagramed in the following attachments. Wells will be insulated from overlying strata with threaded conductor casing and cemented in place in accordance with accepted Halliburton guidelines. The conductor casing, centralizers, and all downhole materials will be steam cleaned before placement. Proper steps will be taken during mixing of and annular placement of the grout. The well will stand for 24 hours to insure that the annular seal has cured. A sample of the grout will be placed in a container under water and checked as proof the grout has set before additional drilling will be allowed to continue.

The field geologists and drillers will be trained in-house and then in the field with practical application of the Halliburton cementing procedures. Field personnel will not be allowed to attempt grouting until the ESE Geotechnical Supervisor verifies their qualification. The supervisor will then observe placement to confirm that cementing is done according to specification.

Prepared by,

Zachary A. Smith /MEM

Zachary A. Smith, P.E.
Task Manager

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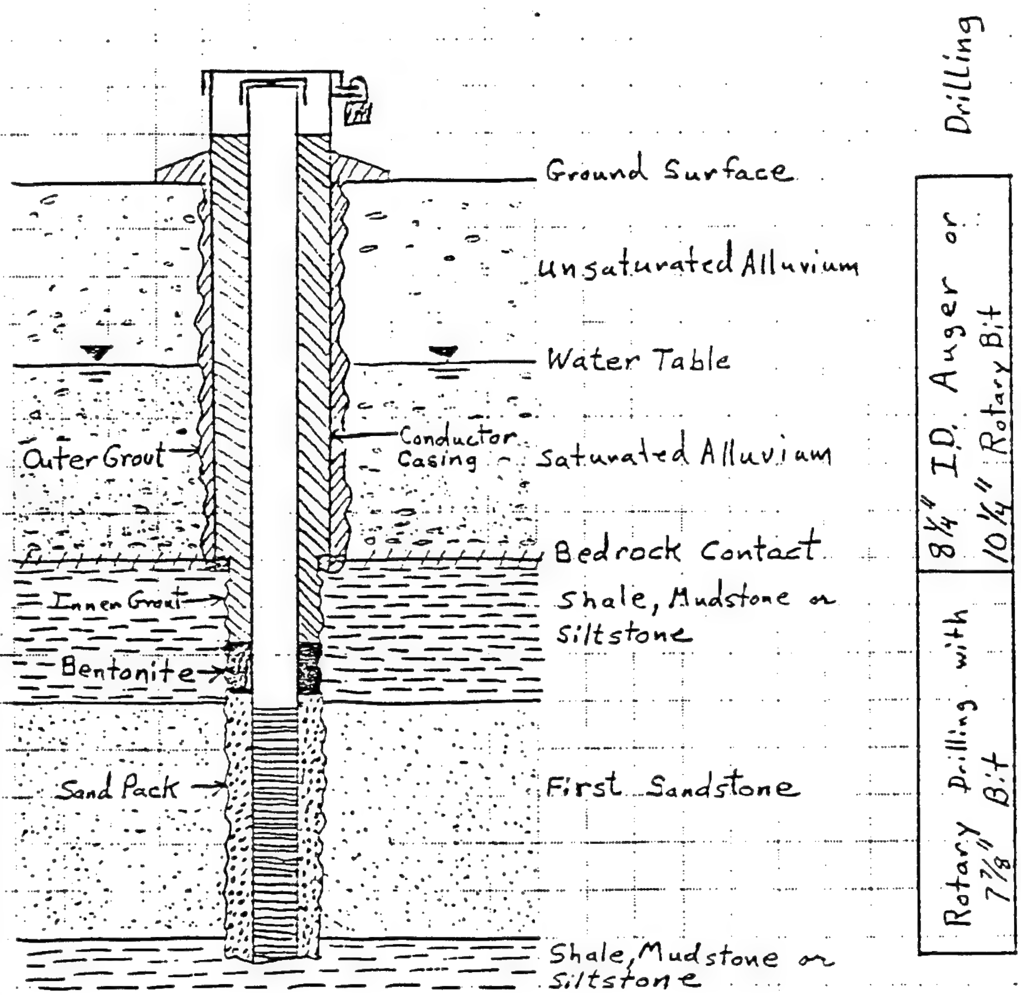
JOB RMA 4" Monitoring Well, Denver Fm
SHEET NO. 1 OF 7
CALCULATED BY Roy L. Cox DATE Nov. 24, 1986
CHECKED BY ________ DATE ________
SCALE None

DENVER FM. WELL COMPLETED in FIRST SANDSTONE, Alluvium Saturated, Shale at the Alluvial-Bedrock Contact.



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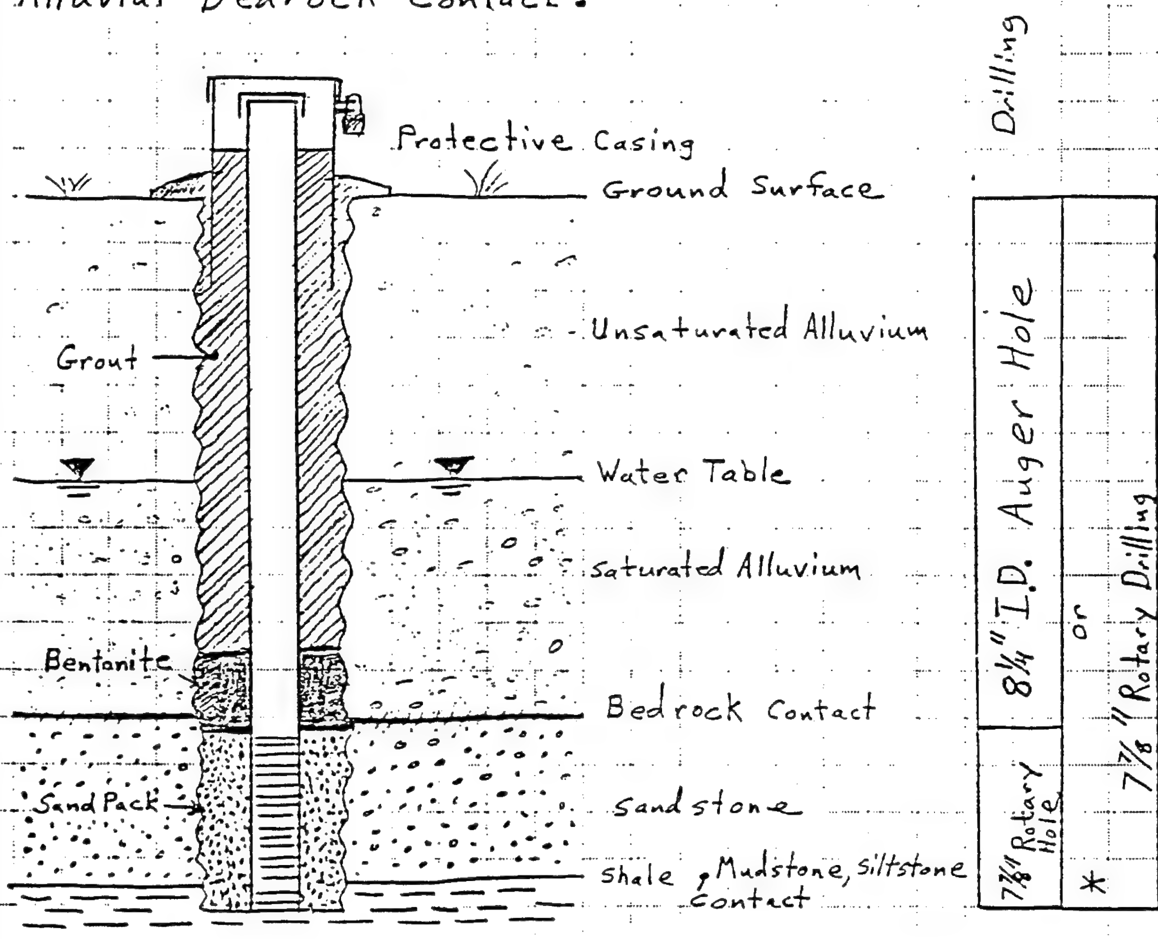
JOB RMA 4" Monitoring Wells, Denver Fm
SHEET NO. 2 OF 7
CALCULATED BY Roy L. Cox DATE Nov. 24, 1986
CHECKED BY DATE
SCALE None

DENVER FM. WELL COMPLETED in FIRST SANDSTONE, Alluvium Saturated, Sandstone at the Alluvial-Bedrock Contact.



*Field Determination after Drilling Alluvium

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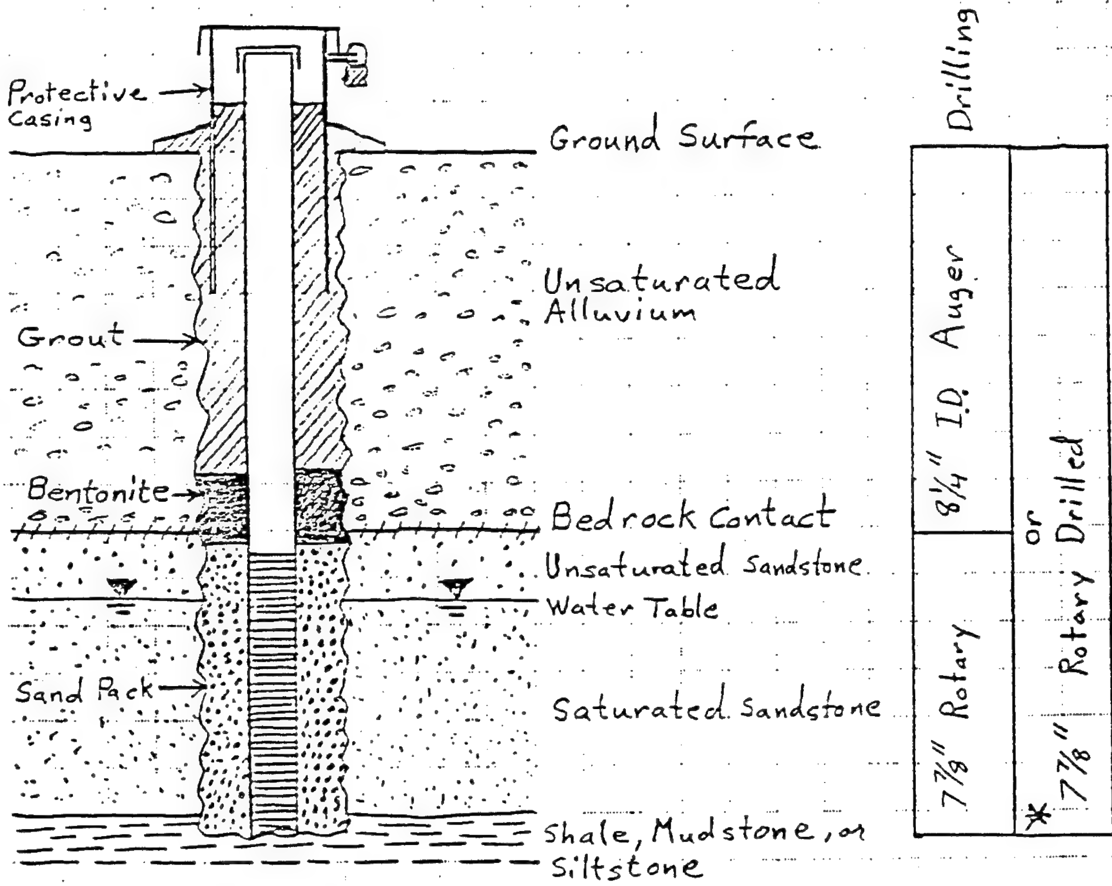
JOB RMA 4" Monitoring Wells, Denver Fm
SHEET NO. 3 OF 7
CALCULATED BY Roy L. Cox DATE Nov. 24, 1986
CHECKED BY DATE
SCALE None

DENVER FM. WELL COMPLETED in FIRST SANDSTONE, Alluvium Unsaturated, Sandstone at the Alluvial-Bedrock Contact; Sandstone Partially Saturated.



* Field Determination after Drilling Alluvium

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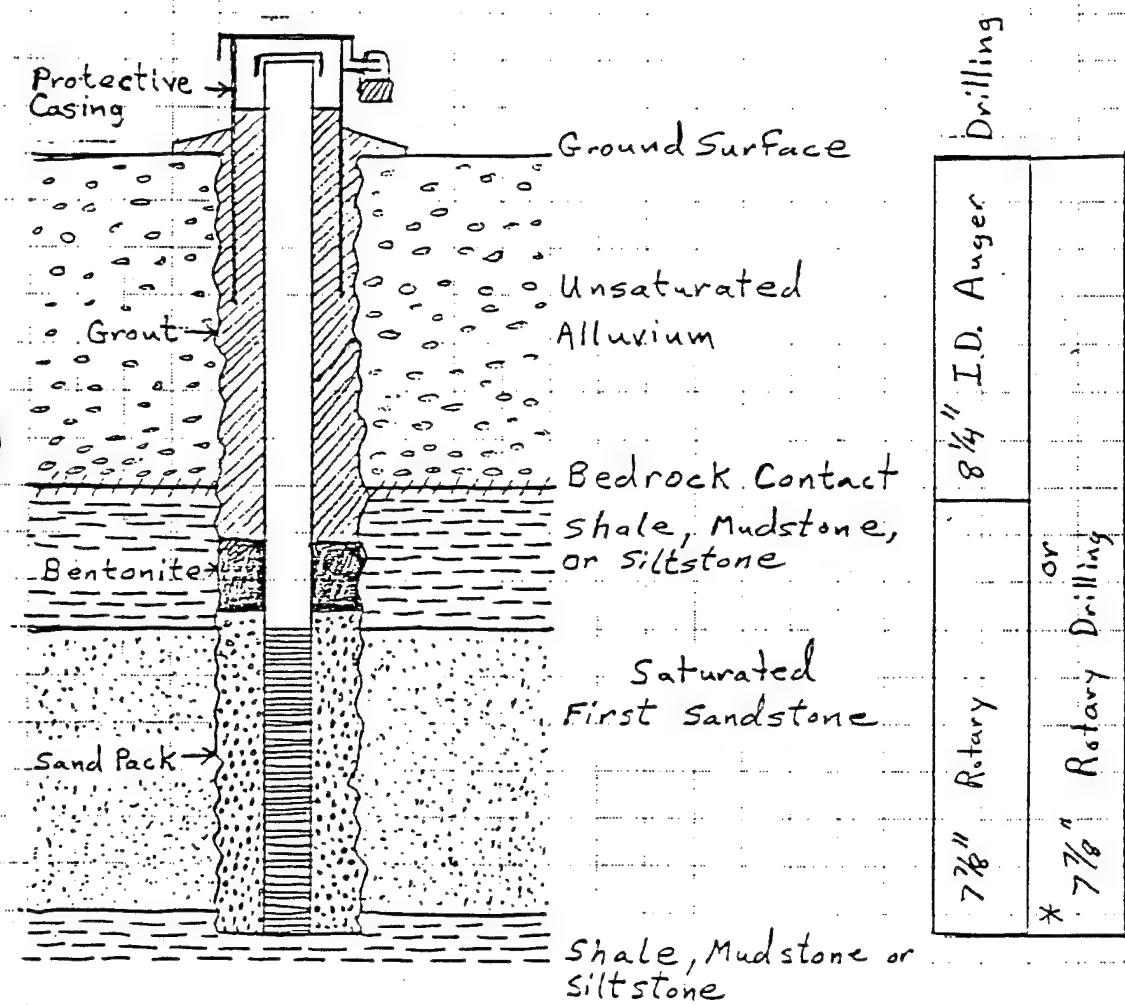
JOB RMA 4" Monitoring Wells, Denver Fm
SHEET NO. 4 OF 7
CALCULATED BY Roy L. Cox DATE Nov. 24, 1986
CHECKED BY DATE
SCALE None

DENVER FM. WELL COMPLETE in the FIRST SANDSTONE, Alluvium Unsaturated, Shale at the Alluvial-Bedrock Contact



*Field Determined after Drilling Alluvium

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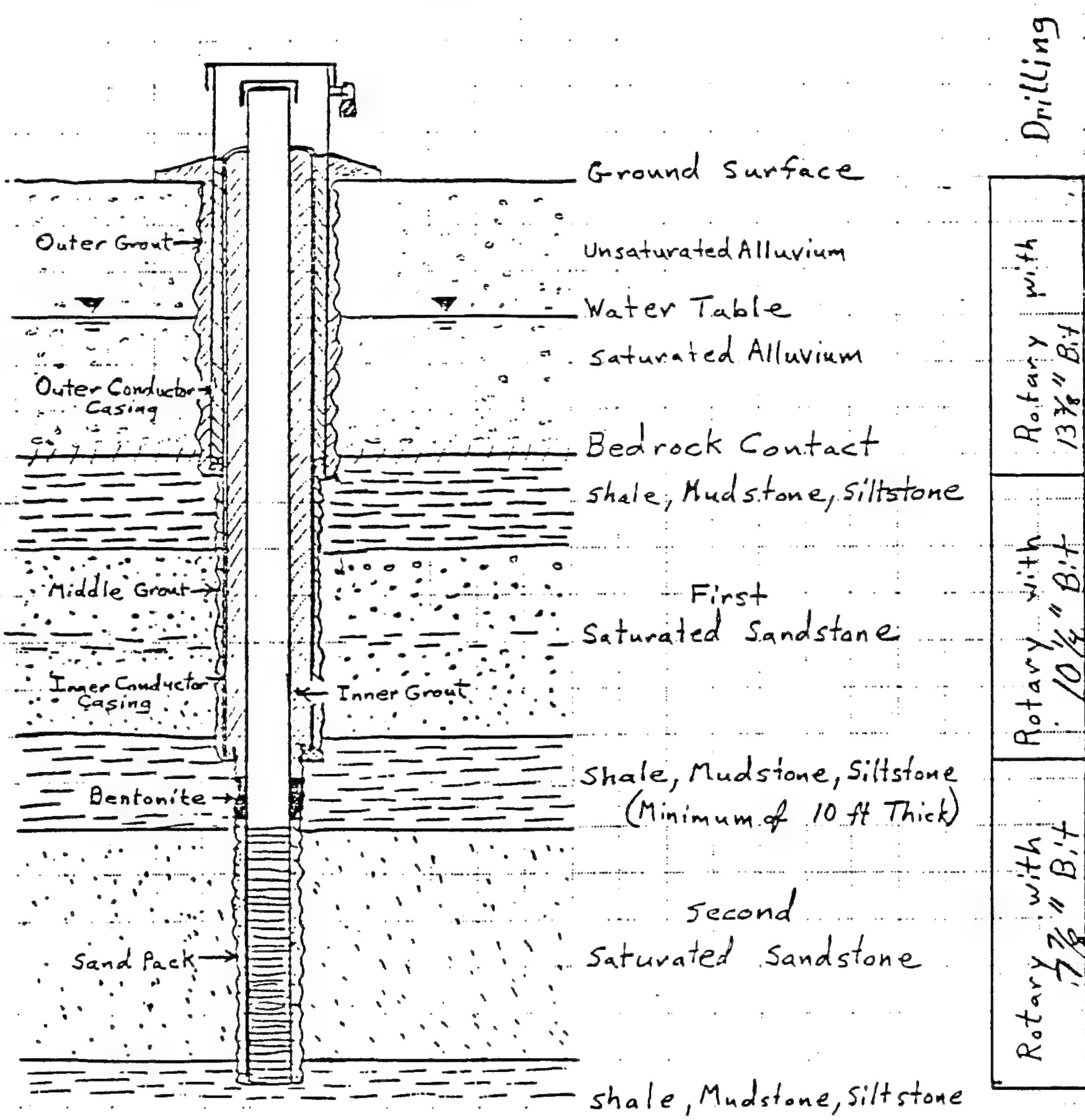
JOB RMA 4" Monitoring Wells Denver Fm
SHEET NO. 5 OF 7
CALCULATED BY Roy L. Cox DATE Nov. 24, 1986
CHECKED BY DATE
SCALE None

DENVER FM. WELL COMPLETED in SECOND SANDSTONE, Alluvium Saturated, Shale at the Alluvial-Bedrock Contact.



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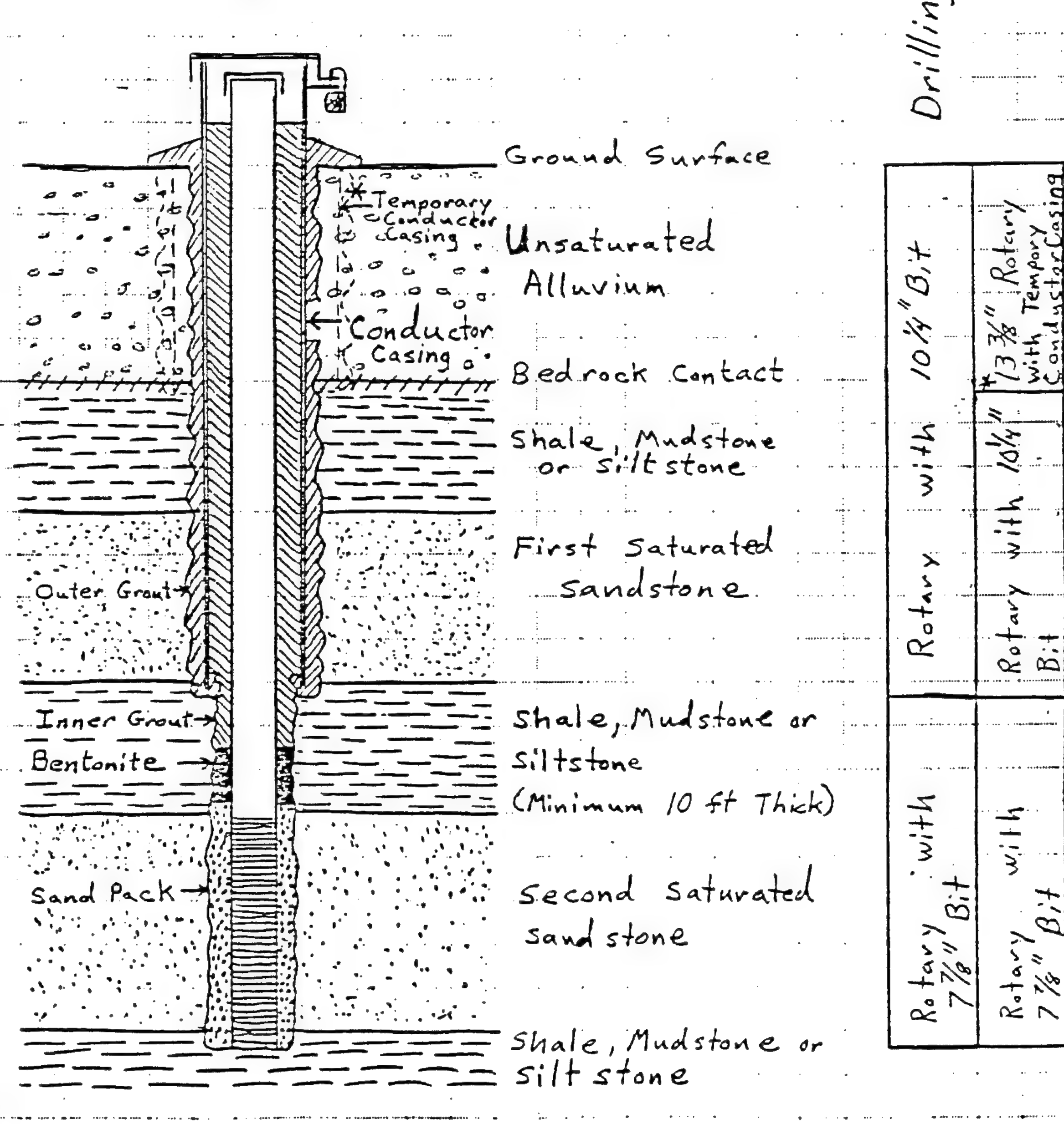
JOB RMA 4" Monitoring Wells
SHEET NO. 6 OF 7
CALCULATED BY Roy L. Cox DATE Nov. 24, 1986
CHECKED BY ______ DATE ______
SCALE None

DENVER FM. WELL COMPLETED in the SECOND SANDSTONE, Alluvium Unsaturated, Shale at the Alluvial-Bedrock Contact, First and Second Sandstone Saturated.



* Field Determination after Drilling Alluvium

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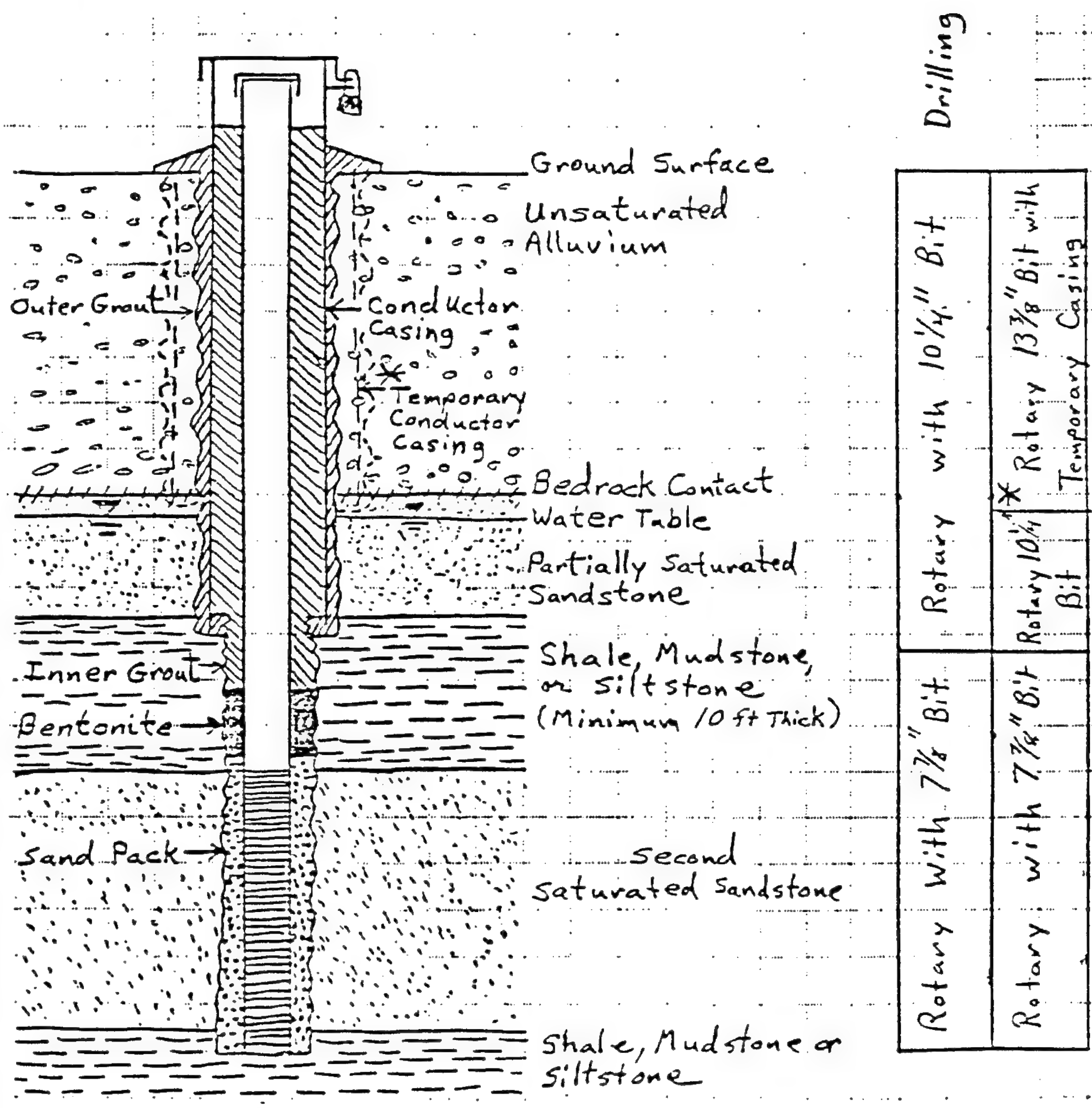
JOB RMA 4" Monitoring Wells Denver F.
SHEET NO. 7 OF 7
CALCULATED BY Roy L. Cox DATE Nov. 24, 19
CHECKED BY DATE
SCALE None

DENVER FM. WELL COMPLETED in the SECOND SANDSTONE, Alluvium Unsaturated, Saturated Sandstone at the Alluvial-Bedrock Contact



* Field Determination after Drilling Alluvium

August 14, 1986

Project No. 86942, 86946, and Task 36

Letter Technical Plan

RE: Combined Offpost Borehole and Monitor Well Drilling Program
Task 25, 36, and 39

ESE, Inc. has prepared a comprehensive drilling program incorporating elements of the borehole/corehole and monitor well drilling programs of Tasks 25, 36, and 39. This proposed Offpost drilling program was prepared by a committee composed of ESE's hydrogeologist, geochemists, geologists, and engineers involved in each of these tasks. Also, comments and recommendations made by Brian Anderson of the RMA-PMO, James May of the Corps of Engineers, and yourself have been considered and incorporated into the proposed drilling program.

Briefly, the proposed drilling program is designed to be flexible yet still provide adequate geologic ground water and geochemical information.

The location of well sites, the number of wells per site, and completion intervals for each well are not rigidly fixed at this point. Well sites which appear on the enclosed map, Attachment A, represent the general location where data is needed and where physical access is best. The precise location of wells will depend on the U.S. Army Corps of Engineers obtaining right of entries, access ways and right-of-ways, and results of the geophysics and borehole/corehole drilling.

The boreholes/coreholes and monitoring wells will be completed in both the alluvial material and the sandstones of the Denver Formation. Cluster well sites will consist of one alluvial well paired with one or two Denver Formation wells. At sites with 2 Denver wells, the wells will

be completed within the first and second sandstone aquifers encountered during drilling.

The installation of Denver Formation monitoring wells will be concentrated within an area 1½ miles north of the arsenal and west of Potomac Street to Colorado Route 2. The Denver wells are concentrated in this area since this area is where the Denver sandstones which subcrop under RMA also subcrop in the Offpost.

Enclosed are copies of the following materials:

1) Map titled "Proposed Well and Boring Sites with Locations of Existing Wells", Attachment A;

2) Table titled "Proposed Activities at Drill Sites", Attachment B; and

3) Site descriptions.

Prepared by,

Roy L. Cox /mem

Roy L. Cox
CPGS #6556

ATTACHMENT B
PROPOSED ACTIVITIES AT DRILL SITES

Tabl B "P sed ivi s at ill es"

ESE Site	Quarter/ Quarter Section Location	*Owner	Existing Well	Geophysics Line	Proposed Number of Wells	Alluvial Well	Intermediate Denver Well	Low Denver Well
E-32	NW/4 NW/4-24	RMA	24093(A11)	No	2	---	yes	yes
-33	NW/4 NW/4-24	RMA	24163(A11)	No	2	---	yes	yes
-34	SE/4 SW/4-13	A	37338(A11)	No	2	---	yes	yes
-35	NE/4 NE/4-24	RMA	-	No	bore only	---	---	---
-36	SE/4 SE/4-13	A	-	yes	3	yes	yes	yes
-37	SE/4 SE/4-15	A	-	yes	3	yes	yes	yes
-38	SW/4 SW/4-14	S	-	yes	(2-3)	may be dry	yes	yes
-39	SE/4 SW/4-14	P	-	yes	3	yes	yes	yes
-40	SW/4 SE/4-14	P	37305	No	2	---	yes	yes
-41	SE/4 SE/4-14	P	37304	No	2	---	yes	yes
-42	SE/4 SE/4-14	P	-	No	3	yes	yes	yes
-43	NE/4 SW/4-14	P	-	yes	bore only	---	---	---
-44	NW/4 SE/4-13	P	-	yes	3	yes	yes	yes
-45	NW/4 SW/4-13	A	37323	yes	2-3	?	yes	yes
-46	NW/4 SW/4-13	P	-	yes	3	yes	yes	yes
-47	NE/4 SW/4-13	P	-	yes	3	yes	yes	yes
-48	NW/4 SE/4-13	P	-	yes	bore only	---	---	---
-49	NW/4 SW/4-18	A	37327	No	2	---	yes	yes
-50	SW/4 NE/4-14	S	-	yes	1	yes	---	---
-51	NW/4 NE/4-14	S	37342	yes	2	---	yes	yes
-52	SE/4 SE/4-11	A	-	yes	1	yes	---	---
-53	SW/4 SE/4-12	A	-	yes	3	yes	yes	yes
-54	SW/4 SE/4-12	A	-	yes	3	yes	yes	yes
-55	NE/4 SW/4-22	A?/P?	-	yes	1	yes	---	---
-56	NE/4 SE/4-15	P	-	yes	1	yes	---	---
-57	SW/4 SE/4-11	S	-	yes	1	yes	---	---
-58	NE/4 SE/4-11	A	-	yes	1	yes	---	---
-59	SE/4 NW/4-12	S	-	yes	1	yes	---	---
-60	SW/4 NW/4-15	UP/ RR	-	yes	1	yes	---	---
-61	SW/4 SW/4-11	A	-	---	1	yes	---	---
-62	SE/4 NW/4-11	P	-	yes	1	yes	---	---
-63	SW/4 SW/4-13	P	-	yes	3	yes	yes	yes
-64	NW/4 NW/4-13	A	-	yes	3	yes	yes	yes

*Owner Code

P=Private Owner S=State Hwy. Dept. RMA=Rocky Mountain Arsenal

A=Adams County Hwy. Dept UP/RR=Union Pacific Railroad

ATTACHMENT C
SITE DESCRIPTIONS

INTRODUCTION

This is to request access to Colorado Department of Highways owned right-of-way along Highway 2 and Highway 44 (East 104th Avenue west of Highway 2). Access will be needed for the purpose of ground water monitoring activities. These will include the drilling of boreholes and the installation of monitoring wells as well as long-term ground water sampling of the wells on a quarterly basis. Access will be needed for six sites which are described by Section as follows.

Section 14 (T2S, R67W)

E-38 is a site for the installation of a cluster of three wells along the west side of Highway 2, approximately 1,200 feet (ft) northeast of the intersection of East 96th Avenue. The site is 900 ft east of the west section line and 900 ft north of the south section line lying in the southwest quarter, southwest quarter of Section 14.

E-50 is a site for the installation one or more wells along the west side of Highway 2. It is 3,100 ft east of the west line and 3,500 ft north of the south line of Section 14 and lies in the southwest quarter, northeast quarter of Section 14.

E-51 is at the site of an existing shallow well where an additional 1 or 2 wells will be installed. The site is approximately 3,800 ft east of the west line and 4,300 ft north of the south line of Section 14 in the northwest quarter, northeast quarter of Section 14.

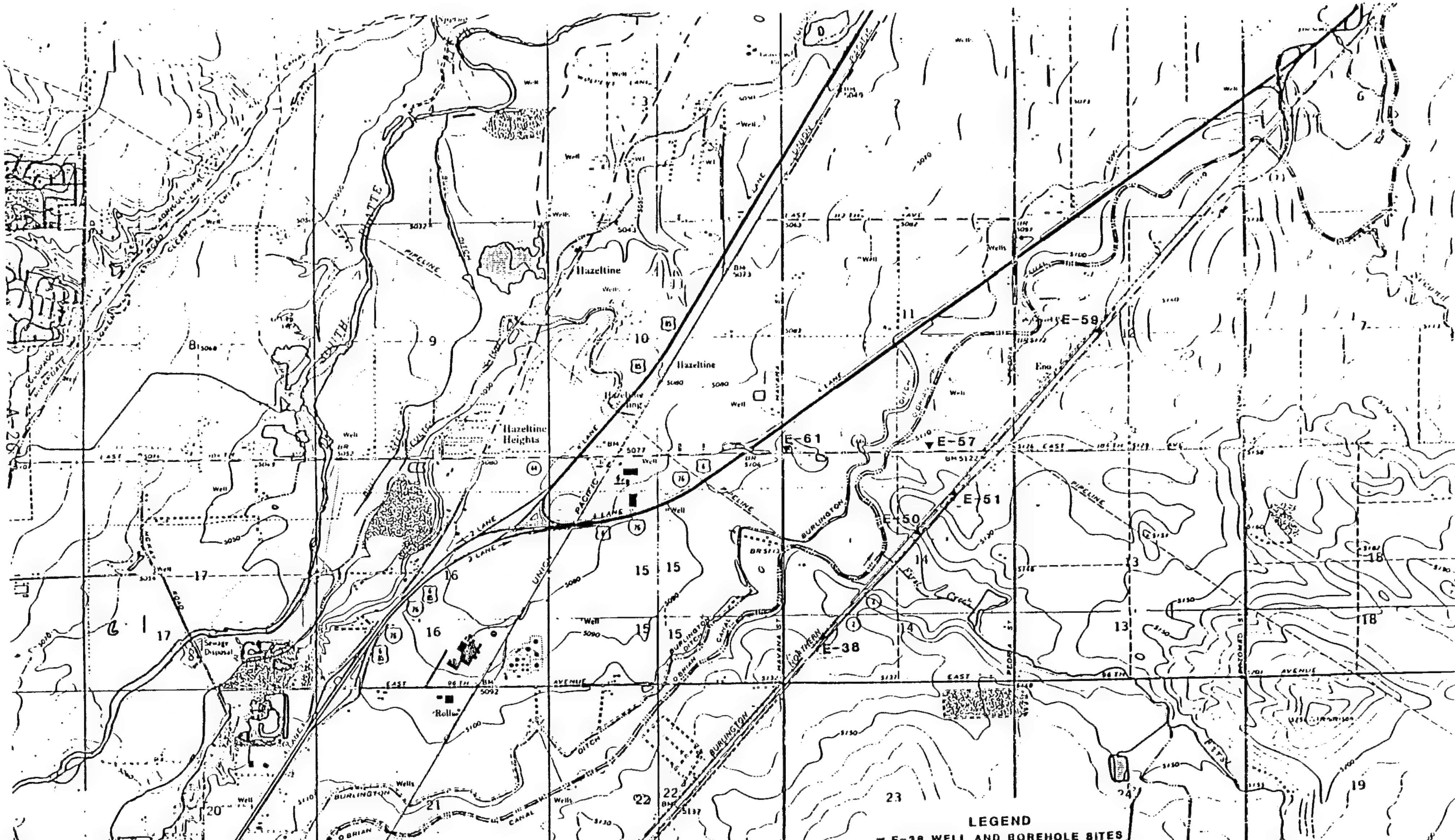
Section 11 (T2S, R67W)

Site E-57 is along the north side of Highway 44 (East 104th Avenue west of the junction with Highway 2) which runs along the south line of Section 11. The site is about 3,500 ft east of the west line and 30 ft north of the south line lying in the southwest quarter, southeast quarter of Section 11.

Site E-61 also is along the north side of Highway 44 approximately 100 ft east of the west line and 30 ft north of the south line in the southwest quarter, southwest quarter of Section 11.

Section 12 (T2S, R67W)

Site 59 lies along the northwest side of Highway 2, approximately 1,900 ft east of the west line and 2,800 ft north of the south line in the southeast quarter, northwest quarter of Section 12.



LEGEND

▼ E-38 WELL AND BOREHOLE SITES

PROPOSED ARMY CORPS OF ENGINEERS' RIGHT-OF-WAYS ON COLORADO DEPARTMENT OF HIGHWAYS LA

DRAWING TITLE

INTRODUCTION

This is to request access to Adams County owned highway right-of-way for the purpose of ground water monitoring activities. This will include the drilling of boreholes and the installation of monitoring wells as well as long-term ground water sampling on a quarterly basis. Access is needed for nine sites along the following county roads: Havana, Peoria, and Potomac Streets and East 96th and East 104th Avenues. These sites are described by Section as follows.

Section 15 (T2S, R67W)

Site E-37 is along the west side of Havana Street, 800 ft north of the south line and approximately 20 ft west of the east line of Section 15 and is in the southeast quarter, southeast quarter of Section 15.

Section 13 (T2S, R67W)

Site E-34 is along the north side of East 96th Avenue at an existing shallow monitor well site that is 2,500 ft east of the west line and 20 ft north of the south line in the southeast quarter, southwest quarter of Section 13.

Site E-36 is along the west side of Potomac Street approximately 20 ft west of the east line and 500 ft north of the south line in the southeast quarter, southeast quarter of Section 13.

Site E-45 is along the east side of Peoria Street about 20 ft east of the west line and 2,700 ft north of the south line of Section 13 lying in the northwest quarter, southwest quarter of Section 13.

Site E-64 is along the east side of Peoria Street approximately 4,000 ft north of the south line and 20 ft east of the west line of Section 13. The site lies in the northwest quarter, northwest quarter of Section 13.

Section 18 (T2S, R66W)

Site E-49 lies along the east side of Potomac Street about 2,600 ft north of the south line and 20 ft east of the west line in the northwest quarter, southwest quarter of Section 18.

Section 12 (T2S, R67W)

Site E-53 is along the north side of East 104th Avenue approximately 900 ft east of the west line and 20 ft north of the south line in the southwest quarter, southwest quarter of Section 12.

Site E-54 is along the north side of East 104th Avenue approximately 3,300 ft east of the west line and 20 ft north of the south line in the southwest quarter, southeast quarter of Section 12.

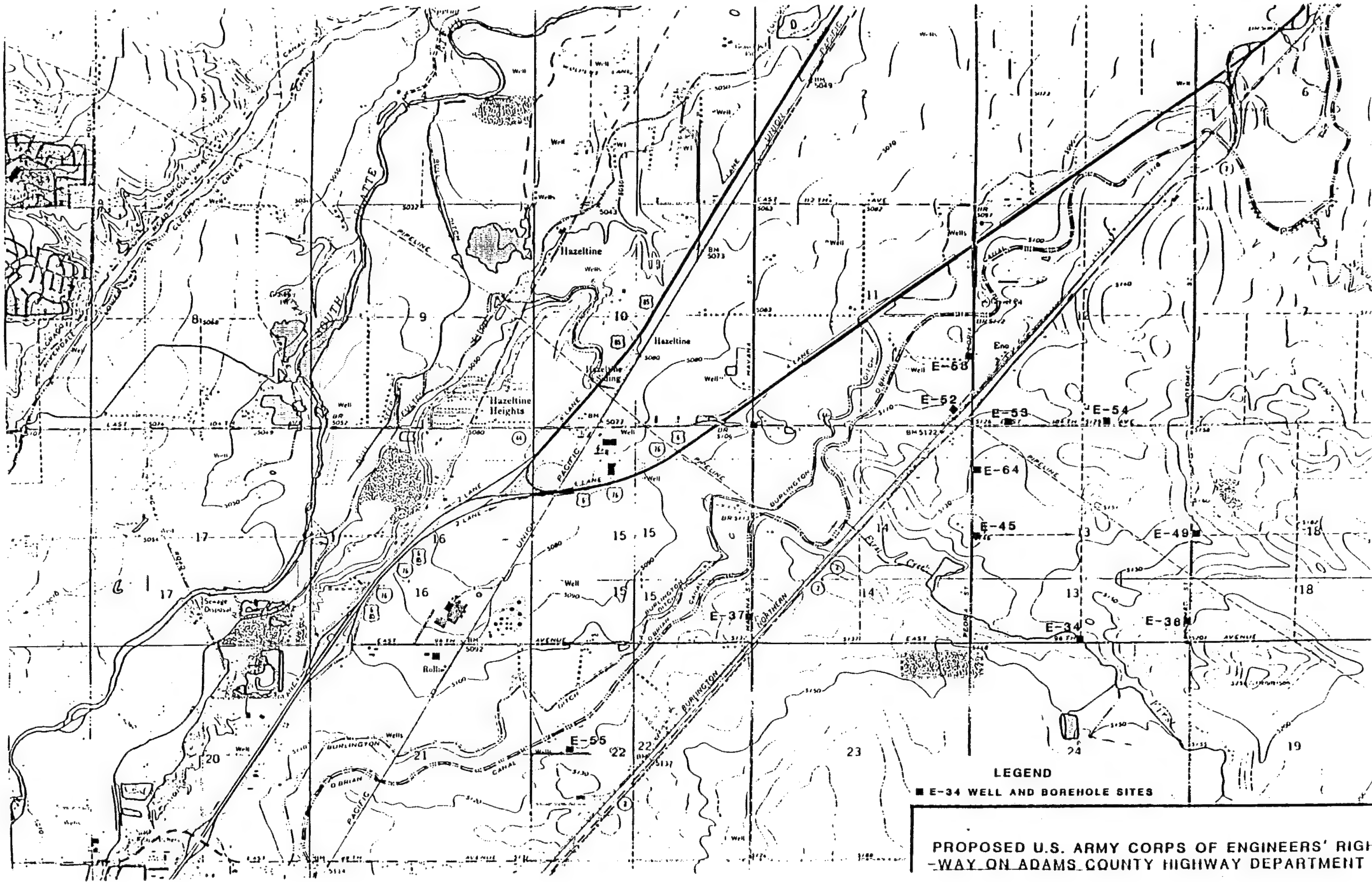
Section 11 (T2S, R67W)

Site E-52 is along the northwest side of Peoria Street approximately 500 ft northeast of the intersection with East 104th Avenue. This site is in the southeast quarter, southeast quarter of Section 11 approximately 400 ft west of the east line and 400 ft north of the south line of Section 11.

Site E-58 is along Peoria Street on the west side about 1,700 ft north of the south line and 20 ft west of the east line in the northeast quarter, southeast quarter of Section 11.

SECTION 22 (T2S, R67W)

Site E-55 is along East 92nd Avenue on the north side of the roadway. The site is in the southwest quarter, northwest quarter of Section 22 approximately 2,700 ft north of the south line and 1,200 ft east of the west line. (This site may be on Burlington Northern Railroad property. See private ownership section [Section 22]).



PROPOSED U.S. ARMY CORPS OF ENGINEERS' RIGHT
-WAY ON ADAMS COUNTY HIGHWAY DEPARTMENT L

INTRODUCTION

This is a request for easement and access onto privately owned property for the purposes of ground water monitoring activities. The proposed activities will include any or all of the following: preliminary geophysical surveys, the drilling of boreholes, the installation and completion of monitoring wells, and the long-term sampling of ground water in the wells on a quarterly interval. The exact locations of borehole sites is dependent upon the completion of the preliminary geophysical surveys. The locations of most of the permanent monitor well installations will hinge upon the data collected both in the geophysical and borehole programs. Some sites have been pre-selected because of the location of an existing monitoring well, but most sites were selected to minimize disturbance and inconvenience to private land owners by being placed along property boundaries and fence lines where practical. All sites will be regraded and seeded to return the site to original condition. Permanent well sites will cover a 5 foot to 20 foot square area. These sites will contain one to three wells completed in the alluvium and/or the Denver Formation.

The individual sites and property owners involved are listed below by Section as well as a discussion of the activity level anticipated for each site. A detailed description of each type of activity is included at the end to indicate the type of short-term and long-term access needed as well as the amount of short-term physical disturbance and the long-term presence of physical objects such as well casings.

SITE LOCATIONS

Section 13 (T2S, R67W)

E-43, E-46, E-47, and E-63 are sites located on property denoted by tax record 1721-00-0-00-030 in the southwest quarter of Section owned by:

Adams County Joint Venture
% Butler and Pierce
720 Kipling Street, Suite 201
Lakewood, Colorado 80215
(303) 232-3888

A fifty foot easement and corridor of access is requested along the northern, eastern and southwestern property lines of the property to conduct a preliminary geophysical survey to drill several borings and install monitoring wells. Site E-46, E-47, and E-63 are the proposed well locations. There will be three wells installed at each of the well sites. E-43 is the location of a borehole site. We will be requesting continued access along the north and southwest corridors for quarterly monitoring (every 3 months). The exact locations for these wells and bores will be determined after the completion of the geophysical survey.

Section 14 (R2S, R67W)

Site E-39 is located on property denoted by tax record 1721-14-0-05-005 in the southeast quarter of the southwest quarter of Section 14 owned by:

City of Commerce City
% Gregg Clements
4407 E. 60th Avenue
Commerce City, Colorado 80022
(303) 289-3701

Currently being dryland wheat farmed by Hickey Farms

% Charles Hickey
3240 Jay Street
Wheatridge, Colorado 80033
(303 233-9003

A 50 ft easement and corridor of access is requested for the eastern property line of Block 5 of the Adco Industrial Park Subdividion in Section 14 which runs from the center point of Section 14 due south to the midpoint of the south section line of Section 14 (96th Avenue). This is needed to run a preliminary geophysical survey, drill a boring and install a permanent cluster of three monitor wells at or near site E-39.

Site E-48 is located on property denoted by property tax record number 1721-00-0-00-007 in the center of the east half of Section 13 on property owned by:

Box Elder Farms Company
1125 17th Street, Suite 2500
Denver, Colorado 80202
(303) 371-5026

A 50 ft easement is requested for temporary access along a corridor from the center point of Section 13 due eastward to the east section line (Potomac Street) for the purpose of running preliminary geophysics and drilling one or more borings. It is planned at this time to drill the proposed boring(s) and then abandon the site following approved well abandonment and reclamation procedures. No further access is expected after the boring(s) are completed.

Site E-40 is located on property denoted by tax record number 1721-14-0-04-020 in the southwest quarter of the southeast quarter of Section 14, approximately 2,000 ft west of the east line and 1,300 ft north of the south line. This property is owned by:

Michael Bruce Collins
11515 East 96th Avenue
Commerce City, Colorado 80022
(303) 288-5969

The access to this property is needed to install two more monitoring wells adjacent to an existing shallow well after an initial boring is completed at the site. An easement of 20 ft along the eastern edge of the property or a satisfactory route chosen by the land owner is requested. Future access to sample this well cluster will be needed on a periodic basis.

Site E-41 is located on property denoted by tax record number 1721-14-0-04-019 which lies in the southeast corner of the southeast corner of Section 14 approximately 1,300 ft west of the east line and 600 ft north of the south line and is owned by:

Dorothy Lambert
11921 East 96th Avenue
Commerce City, Colorado 80022
(303) 287-2733

The access to this site is needed to drill a boring and install two monitoring wells adjacent to an existing shallow monitoring well. The total permanent area of disturbance would be a 20 ft by 20 ft area adjacent to the fence. Future access to the cluster of wells would be needed for periodic ground water sampling on a quarterly basis. This land is currently up for sale by the owner.

Site E-42 is located on property denoted by tax record number 1721-14-0-04-015 in the southeast quarter of the southeast quarter of Section 14, approximately 400 ft west of the east line and 660 ft north of the south line. The property is owned by:

Dorothy Lambert
11921 East 96th Avenue
Commerce City, Colorado 80022
(303) 287-2733

A 50 ft easement and corridor of access along the northern boundary of the property or any other suitable route of access as directed by the property owner is requested to gain access to the site to drill a test boring and install a cluster of three monitor wells. Total permanent disturbance will be an area around the well cluster 20 ft by 20 ft. Future access on a quarterly basis to sample the wells will be needed.

Site E-44 is located on property denoted by tax record number 1721-14-0-00-027 in the northwest quarter of the southeast quarter of Section 14 approximately 1,600 ft west of the east line and 1,900 ft north of the south line. This property is owned by:

Charles Hickey and Michael E. Hickey
3240 Jay Street
Wheatridge, Colorado 80033
(303) 233-9003

We are requesting access to this site along a 40 ft wide easement along the drainage of First Creek southeastward from Highway 2 or along any other suitable corridor as suggested by the property owner. Access is needed to conduct a preliminary geophysical survey along the corridor to drill a test boring in a suitable site at or very near the proposed site based on the geophysics, and to install and complete a cluster of two to three monitor wells. The total area of permanent disturbance will be a 20 ft by 20 ft area around the well cluster. In addition, future access to the monitor well site for quarterly sampling will be needed.

Section 22 (T2S, R67W)

Site E-55 is on property denoted by tax record number 1721-22-0-05-001 in the northeast quarter of the southwest quarter of Section 22 approximately 1,500 ft east of the west line (Yosemite street) and 2,600 ft north of the south line (East 88th Avenue) along the south side of East 92nd Avenue on property owned by:

Burlington Northern Railroad
% ATTN: V.D. McKnire
777 Taylor Room 906
P.O. Box 943
Ft. Worth, Texas 76101

Access to this site is requested along an easement coinciding with the proposed location of East 92nd Avenue from Yosemite Street. The access is needed to drill a test boring and install a monitor well or cluster of wells. Future access to sample the ground water in this well(s) will be needed. (This property may be a right-of-way owned by Adams County. See Adams County Section).

Section 15 T2S, R67W)

Site E-56 is located on land denoted by property tax record number 1721-15-0-00-020 in the northeast quarter of the southeast quarter of Section 15 approximately 1,500 ft west of the east line and 2,000 ft north of the south line. This property is owned by:

Mollie Heinze
% Dave Heinze
10131 E. 96th Avenue
Henderson, Colorado 80640
(303) 268-1600

The site is just northwest of the Burlington Ditch and access is anticipated to be by the "ditch rider road" along the ditch northeastward from E 96th Avenue. A 40 ft corridor of access and easement is requested to conduct a preliminary geophysical survey, drill a test bore, and install and compete one monitoring well at the proposed sit . Total permanent disturbance will be 5 ft by 5 ft area around the well. Future access will be needed for quarterly sampling on a quarterly basis.

Site E-60 is located on property that is the right-of-way of the Union Pacific Railroad Company. Contact:

Union Pacific Railroad Company
Office of Director-Real Estate
Omaha, Nebraska

The proposed site is 50 ft east of the west line and 2,600 ft north of the south line in the northwest corner of the southwest corner of Section 15.

A 50 ft easement and corridor of access is requested located along the side of the railroad tracks to perform a preliminary geophysical survey, drill a test boring and install a monitoring well at or very near the proposed site. The total permanent disturbance will be a 5 ft by 5 ft area around the well. This well will require future access along the railroads access road for quarterly ground water sampling. The well location will be a minimum of 50 ft east of the center line of the railroad tracts.

Section 11 (T2S, R67W)

Site E-62 is located on property denoted by tax record number 1721-11-0-00-008 in the center of Section 11 approximately 2,600 ft south of the north line and 2,600 ft east of the west line of Section 11 on property owned by:

Glenn A. Murray Trust
11010 Havana Street
Route 3, Box 166A
Henderson, Colorado 80640
(303) 288-2998

Access to the site is requested along either of the private roads that run along the east or south boundaries of the property. This will give access from either Havana Street or East 112th Avenue. The site is proposed to be adjacent to the Burlington Ditch. Activities at the site would include preliminary geophysics, a test borehole, and completion and installation of a monitoring well based on the geophysical results. The total permanent disturbance will be an area around the well of 5 ft by 5 ft. Future access to the site is requested for quarterly sampling.

DESCRIPTION OF ACTIVITIES

Geophysics

Running geophysical surveys would entail a short-term access of minimal disturbance from a hand carried instrument or loop of wire that would measure radio frequency impulses. Stations would be surveyed in by a survey crew.

Boreholes

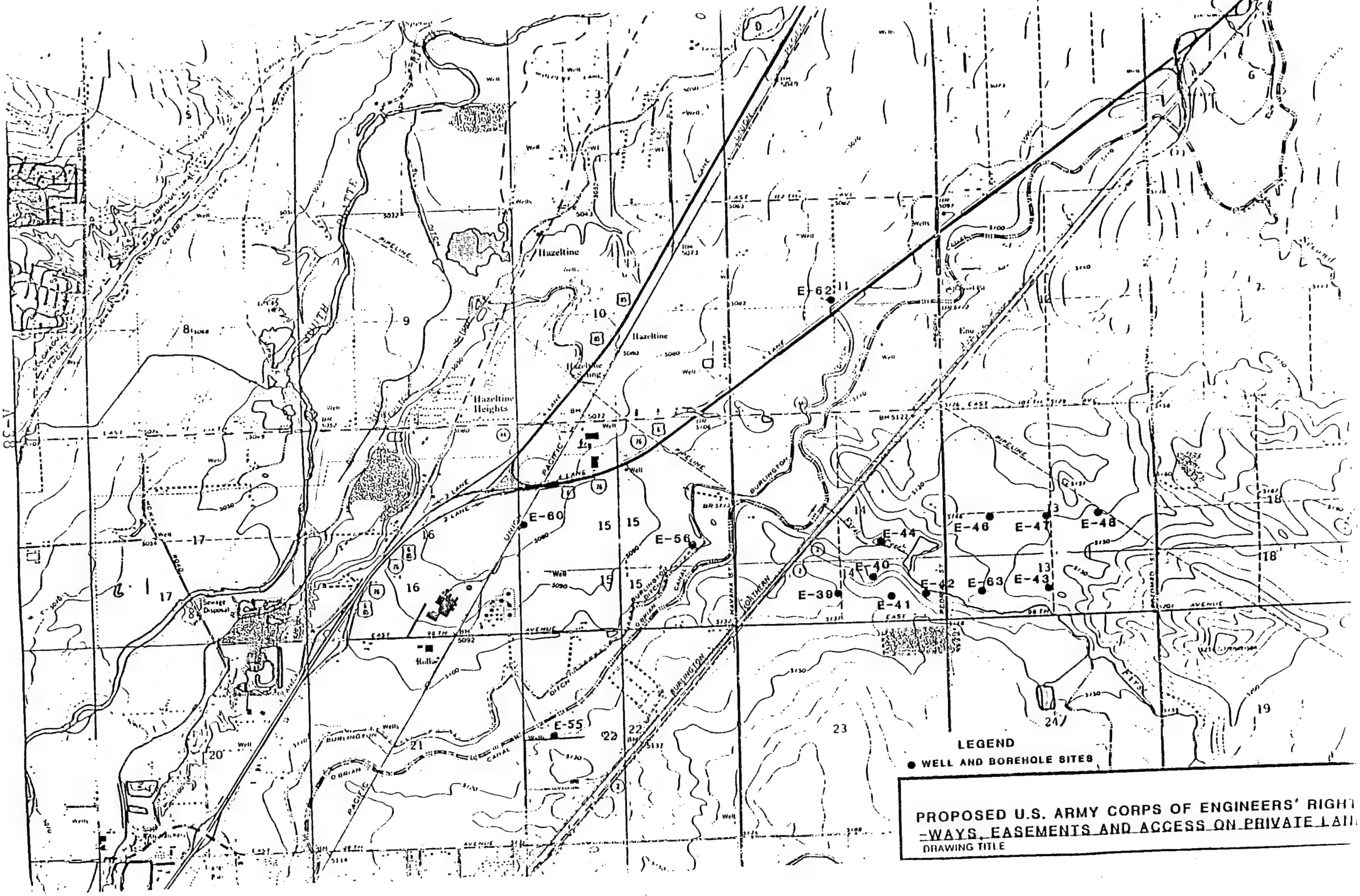
Using data generated during geophysical surveys to pinpoint the most favorable sites for geologic information and monitor well siting, boreholes may be drilled with a medium sized truck-mounted water well drill rig. Support vehicles for drilling would include a water truck and 1 or 2 pickup trucks. Any surface disturbance from boring activities would be regraded and reseeded to pre-site conditions.

Monitor Well Installation

At suitable sites between 1 to 3 monitor wells will be installed in boreholes drilled by the drill rig. The wells will be cased with four inch PVC casing. An eight inch diameter two foot high locked steel protective casing will be installed over the well. Single well sites would only cover an area within a 5 foot square. Cluster well sites with three wells would only cover an area within a 20 foot square. Following the drilling all sites will be regraded and reseeded to correct any minor surface disturbances which may occur.

Long-Term Monitor Well Access

Access to collect periodic ground water samples from the wells on a quarterly basis, would entail access by a one-ton pump truck, a pickup truck with pumping equipment, an ATV (i.e., a 3 or 4 wheel cycle) or even a two person foot mounted crew carrying a small amount of bailing and sampling equipment depending upon access and conditions. Preferred access is by truck followed by ATV and by foot. All attempts at access will be during dry soil conditions to minimize rutting the access way.



PROPOSED U.S. ARMY CORPS OF ENGINEERS' RIGHT -WAYS, EASEMENTS AND ACCESS ON PRIVATE LAN

DRAWING TITLE

June 24, 1987

Project No. 86958

Letter Technical Plan

RE: Evaluation of North Boundary Water Treatment Effectiveness and Clogging of Recharge Wells

INTRODUCTION

The purposes of this subtask are to determine the effectiveness of the North Boundary Water Treatment Plant (NBWTP), to determine why the recharge wells appear to be clogging more than that anticipated and to recommend changes or additions to the treatment plant to improve effectiveness and minimize clogging of the wells. These efforts are grouped together into one subtask because they are closely related and best evaluated together.

The effectiveness of the plant will be measured against its ability to remove the organic and inorganic contaminants listed in Appendix A. Conceptual modifications to the plant will be recommended to remedy any deficiencies noted.

There are several possible reasons for the recharge wells clogging and these relate to the quality of the recharge water. Thus, the quality of the recharge water must be examined to find the major causes. Suspended solids are a highly probable cause, but there may be other substances such as iron or other metals that can precipitate out in the wells. Biological clogging is another factor which will be examined.

The work will be done in three phases to achieve the greatest flexibility and minimize the amount of sampling. Each phase is described below.

SCOPE-OF-WORK

PHASE ONE - PRELIMINARY WATER QUALITY ASSESSMENT

During this phase, we will determine the quality of water entering the treatment plant and the quality of the water leaving the plant. The Task 25 sampling results will be utilized for the organic contaminant concentrations and for the inorganics: arsenic, chloride, fluoride, and sulfate. For the remaining inorganics, we will do additional sampling and analysis under this task.

Influent samples will be taken from each of the three intake lines to the treatment plant. Effluent samples will be collected from the effluent line leaving the treatment plant. This will be used to evaluate changes that are occurring in the plant. For some of the inorganics, samples will also be collected after the effluent sump. The effluent sump may be acting as a settling basin and removing some suspended solids.

The specific contaminants or water quality parameters that will be measured are all organic target contaminants and inorganic contaminants that are contaminants of concern listed in the Preliminary Offpost Response Action Assessment from Task 39 (see Appendix B). In addition, those parameters that may be contributing to the clogging of the recharge wells will be measured. This will be coordinated with the weekly plant sampling occurring under Task 25. Most of the parameters will be analyzed in the laboratory, but some will be measured in the field because of the potential for change before reaching the laboratory. Appendix A contains a complete list of contaminants that will be measured under Task 36.

The water samples will be collected hourly over a seven-hour period and composited. That is, eight samples will be collected from each sampling point and mixed together to obtain one averaged or composited sample from each point. The sampling period will be selected for a time when the treatment plant will be under normal operation so that the samples will be representative of average operating conditions.

Using the available data and the results of the samples collected, we will compare the results with the preliminary Applicable or Relevant and Appropriate Requirements (ARAR) levels developed for the offpost feasibility study to see if the NBWTP is effective in meeting these standards.

We will evaluate the results of analyses to see if we can relate the clogging of the wells to one or more quality parameters. Suspended solids and iron are of particular interest, and we will look closely at their impact on the clogging of the recharge wells.

PHASE TWO - RECHARGE WELL WATER QUALITY ANALYSIS

If the sampling of phase one shows that suspended solids, iron or other substances in the water are of sufficient concentration to cause excessive clogging, we will sample the water in the recharge wells to gain a better understand of the actual water quality in the wells and what changes are occurring after the effluent sump. The amount and type of sampling will be based on the results of Phase One.

Bacteria in water may be fully or partially responsible for high concentrations of iron in the well water. Thus, microbiological analyses may be included in this phase to determine if iron bacteria are present and involved in the oxidation of reduced forms of iron. Other types of bacteria may also be contributing to poor recharge well performance. This scenario will also be investigated under this phase.

If the substances or conditions causing the clogging are identified, we will establish a design criteria for these substances to minimize the excessive clogging.

PHASE THREE - SUPPLEMENTAL TREATMENT ASSESSMENT

If the concentration of any substance is above the maximum allowable levels of contaminants or criteria related to clogging, we will evaluate

alternative treatment processes and schemes to select one or more means of modifying the quality of the water to meet the standards that have been established. The evaluation will include an assessment of possible increased flows to the NBWTP that may be recommended based upon our analysis of the dewatering and recharge system. This will be a desk top evaluation using our professional experience and published data to determine the best way to treat the water. The evaluation will consider the ability of the processes to achieve the desired levels, the capital and O&M costs, and ease of operation. Bench or pilot plant testing will not be performed under this plan.

Prepared by,

Mark E. McClain

Mark E. McClain, P.E.
Senior Associate Engineer

Bob G. Grodt/mem

Bob G. Grodt, P.E.
Senior Environmental Engineer

APPENDIX A
LIST OF CONTAMINANTS

The following list of contaminants will be used to evaluate the effectiveness of the North Boundary Water Treatment Plant and to determine the causes of the excessive clogging of the recharge wells. The contaminants are grouped by the purpose for which they are being measured and the task under which they will be analyzed.

Treatment Plant Effectiveness

Task 25

Aldrin
Benzene
Carbon tetrachloride
Chloroform
MIBK
Dibromochloropropane
1,2-Dichloroethane
Dieldrin
DIMP
Endrin
PCPMSO
Tetrachloroethylene
Trichloroethylene
Isodrin
HCCPD
p'p-DDT
p'p-DDE
DCPD
DMMP
DBCP
PCPMS
DMPDS
1,4-Dithiane
Toluene
m-Xylene
o,p-Xylene
Trans-1,2 Dichloroethene
Trichloroethene
Tetrachloroethene
1,1-Dichloroethylene
Methylene chloride
1,1,1-Trichloroethane
1,2-Dichloroethane
1,1,2-Trichloroethane
PCPMSO2
DCPMSO2
Chlorobenzene

Arsenic
Cadmium
Chloride
Fluoride
Sulfate

Task 36

Cadmium
Lead
Magnesium
Nitrate
Calcium
Sodium
Potassium

Recharge Well Clogging

Task 36

pH
Dissolved oxygen
Acidity
Temperature
Suspended solids
Iron
Total bacteria
Alkalinity
Redox potential
Turbidity
Specific conductivity
Total solids
Manganese

APPENDIX B

Preliminary Contaminants of Concern for Offpost Feasibility Study

Health Based

- Aldrin
- Endrin
- Dieldrin
- pp-DDE
- DBCP
- PCPMSO
- Benzene
- $CHCL_3$
- Carbon Tetrachloride
- Trichloroethene
- Tetrachloroethene
- 1,2-Dichloroethane
- 1,1,2-Trichloroethane
- Fluoride
- Sulfate
- Nitrate
- Sodium
- Arsenic
- Cadmium
- Lead

Organoleptic Based

- Chloride
- Calcium
- Magnesium
- Potassium
- DCPD

May 11, 1987

Project No. 86958

Letter Technical Plan

RE: Task 36, Rocky Mountain Arsenal North Boundary System Component Remedial Action Assessment; Additional Denver Formation Monitoring

As outlined in the Draft Technical Plan, Environmental Science and Engineering, Inc. (ESE) has recommended a program for installation of Denver aquifer wells near the North Boundary Containment System (NBCS). These wells will supplement existing wells and wells being installed under other tasks to assess the water quality and water flows in Denver units near the NBCS. An initial round of well sites were identified in the Draft Technical Plan. As part of the ongoing installation program, additional sites are being identified in this Letter Technical Plan.

The primary objective for the program is to assess the water quality and water flow directions of Denver Formation units which have the greatest likelihood of being contaminated. This approach is being used to provide flexibility in choosing future well installation sites so that wells and borings can be optimized to provide information on the critical Denver sandstone units. Consistent with this philosophy, additional Denver well sites are identified in this Letter Technical Plan (Table 1) and are shown on the enclosed map.

High priority activities are defined as those which are recommended to address specific data requirements and are essential to achieve the primary objectives of the program. These activities will be undertaken first. Moderate priority activities are those which are more effectively undertaken after evaluating geologic, hydrogeologic, and water quality data from drilling and well installation associated with the high priority sites.

All sites have been coordinated with Tasks 25, 39, and 44 to ensure that no two sites provide redundant information. All the proposed wells will

Table 1.

New Site	Activity	Priority	Comments
E-69	Denver Corehole	High	Offpost, new owner, will not permit installation of wells.
EP-19	Pilot Corehole 1st Sandstone Well 2nd Sandstone Well	High High Moderate	Downgradient of barrier, new number for E-66.
EP-20	Pilot Corehole 1st Sandstone Well	High Moderate	Downgradient of barrier.
EP-21	Pilot Corehole 1st Sandstone Well 2nd Sandstone Well	High High Moderate	Downgradient of barrier, new number for E-67.
EP-22	Pilot Corehole 1st Sandstone Well	Moderate Moderate	Downgradient of barrier
EP-25	Pilot Corehole 1st Sandstone Well	Moderate Moderate	Upgradient of barrier
EP-26	Pilot Corehole 1st Sandstone Well	Moderate Moderate	Upgradient of barrier
EP-27	Pilot Corehole 1st Sandstone Well	High High	Upgradient of barrier
EP-28	Pilot Corehole 1st Sandstone Well	High Moderate	Downgradient of barrier

be drilled and constructed according to the details outlined in the Draft Technical Plan. The following summary outlines the locations and rationale for each site:

EP-69

Location: This site is offpost and on private property that was recently purchased by Dennis Spencer Construction. The site is 230 feet (ft) north of 96th Avenue (Ave), and 1,260 ft west of Peoria Street (St) in Section 13. The exact field location is at the discretion of the new landowner.

Rationale: This site is for a corehole to characterize the geology. The owner at this site did not wish to have permanent wells on his property, but was cooperative in allowing permission to drill a boring and gather geologic information. The site will be specifically utilized to define a 1st sandstone unit just upgradient from where it is suspected to subcrop into the alluvium. Thompson, et al. (1985) reported the sandstone unit as being contaminated.

EP-19

Location: This onpost downgradient site is located 1,780 ft west of Peoria St and 210 ft south of 96th Ave in Section 23. Actual field conditions may dictate slight realignment.

Rationale: The pilot corehole and 1st sandstone well at this site are high priority and are recommended for immediate drilling and installation. The pilot corehole is needed to further define the bedrock geology in this area. The 1st sandstone well is required to assess water quality and water levels downgradient from wells located in the same sandstone unit that are closer to the soil-bentonite barrier. Installation of a 2nd sandstone well at this site is a moderate priority.

EP-20

Location: This onpost downgradient site is located 1,100 ft west of Peoria St and 140 ft south of 96th Ave in Section 23. Field conditions may require slight realignment of the site.

Rationale: This site is for drilling of a pilot corehole to collect geologic information on the configuration of sandstone units. Installation of the 1st sandstone well is a moderate priority. The 1st sandstone wells at EP-21 and EP-19 are considered higher priority and will be installed first.

EP-21

Location: This onpost downgradient site is located 650 ft west of Peoria St and 130 ft south of 96th Ave in Section 23. Field conditions may dictate slight site realignment.

Rationale: This site is for drilling a high priority corehole and installing a high priority 1st sandstone well to obtain geologic, water quality, and water level data. A moderate priority 2nd sandstone well is also proposed.

EP-22

Location: This onpost downgradient site is located 1,950 ft east of Peoria St and 220 ft south of 96th Ave in Section 24. Proximity to the bog or other field conditions may necessitate slight realignment of the site.

Rationale: This site is for drilling a moderate priority pilot corehole and installation of a moderate priority 1st sandstone well. These activities will depend upon water quality and water level data obtained from previously installed wells at Sites E-33 and E-34, which are 1st sandstone wells installed just to the east and west of the proposed site, respectively.

EP-25

Location: This onpost upgradient site is tentatively located 850 ft west of Peoria St and 900 ft south of 96th Ave in Section 23. This site may be shifted to another upgradient site depending upon specific data needs.

Rationale: This site is for a moderate priority pilot corehole and 1st sandstone wells. The specific location for this site will be dependent

upon data obtained from wells installed earlier and may be shifted to another upgradient site if information at another site is deemed more critical.

EP-26

Location: This onpost upgradient site is located 210 ft west of Peoria St and 950 ft south of 96th Ave in Section 23. It is at the site of an existing alluvial well 23123.

Rationale: This site is for a moderate priority corehole and 1st sandstone well upgradient of the soil-bentonite barrier. The corehole and well will be utilized to examine upgradient geology, water quality, and water levels in the 1st sandstone unit encountered at this site. The specific location for this site will be dependent upon data obtained from wells installed earlier any may be shifted to another upgradient site if information at another site is deemed more critical.

EP-27

Location: This onpost upgradient site is located 710 ft west of Peoria St and 1,130 ft south of 96th Ave in Section 23. Actual field conditions may require slight realignment of this site.

Rationale: This upgradient site is for a high priority pilot corehole and 1st Denver sandstone well. This drilling and installation will assist in defining geology, water quality, and hydrologic conditions in a major 1st sandstone unit. This well will assist in determining points of entry for contamination into this unit.

EP-28

Location: This onpost downgradient site is located 235 ft south of 96th Ave and 2,480 ft west of Peoria St in Section 23. Actual field conditions may require slight realignment.

Rationale: This site is for drilling a high priority corehole and installation of a moderate priority 1st sandstone well. The corehole will be utilized to define the extent of the 1st sandstone in this

downgradient area. The need to install the 1st sandstone well will be evaluated based upon data obtained from the high priority wells at EP-19 and EP-21.

The next round of additional sites and additional wells at existing sites will be recommended based upon data obtained from the drilling and well installations outlined in this Letter Technical Plan. All additional drilling and well installation will be outlined in a Letter Technical Plan.

Prepared by:

Mark E. McClain

Mark E. McClain

BIBLIOGRAPHY

Thompson, D.W., E.W. Berry, B.L. Anderson, J.H. May, and R.L. Hunt. 1985. North Boundary Containment/Treatment System Performance Report. Vol. I & II. Rocky Mountain Arsenal. Denver, Colorado. RIC#86078R01. 60 p.

APPENDIX B

COMMENTS AND RESPONSES

Memorandum of Agreement (MOA) general comments on this Technical Plan were discussed in MOA meetings of October 29, 1986, February 3, 1987, and October 16, 1987 and discussion is documented in the minutes for these meetings. Also, working session meetings were held on May 19, 1987, May 20, 1987, June 29, 1987, June 30, 1987, and September 1, 1987.

Environmental Protection Agency verbal and written comments have been incorporated in the content of the Final Technical Plan. Specific written comments by MOA parties along with written responses are included in this Appendix. A listing of all the MOA meetings and working sessions is provided below with a description of the topics for each.

MOA MEETINGS

October 29, 1986
MOA Meeting
Presentation of Task 36 Project

February 3, 1987
MOA Meeting
Review of Task 36
Project Discussion of Technical Plan
Composite Well Drilling

October 16, 1987
MOA Meeting Review of Task 36 Project
Composite Well Drilling

MOA WORKING SESSIONS

May 19, 1987
MOA Working Session
Modelling, Well Installation, and Barrelling

May 20, 1987
MOA Working Session
Modelling, Well Installation, and Barrelling

June 29, 1987
MOA Working Session
Task 36 Modelling

June 30, 1987
MOA Working Session
Task 36 Investigation and Data Assessment
Hydrology and Geology

September 1, 1987
MOA Technical Planning Session
Task 36 Technical Program Planning Session
Technical Data, Data Assessment

STATE OF COLORADO

COLORADO DEPARTMENT OF HEALTH

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Roy Romer
Governor

Thomas M. Vernon, M.D.
Executive Director

April 23, 1987

04 MAY RECD

Colonel W. Quintrell
Deputy Program Manager
RMA Contamination Cleanup
Department of the Army
AMXRM-EE, Building 4585
Aberdeen Proving Ground
Maryland, 21010-5401

RE: Task 36, North Boundary Containment/Treatment System (NBCS) Assessment

Dear Colonel Quintrell:

Enclosed are the State's comments on the Draft Final Technical Plan, North Boundary System Component Response Action Assessment, Task Number 36, March 1987. As discussed in the attached comments, we believe the technical plan needs to be revised to meet the objectives of the task and to be consistent with the requirements of the National Contingency Plan and CERCLA as amended. We have two primary concerns with Task 36 as proposed.

Our first concern is that Task 36 does not include an evaluation of the NBCS treatment plant. All previous evaluations of the NBCS carbon adsorption treatment plant have focused on its effectiveness in treating a limited subset of the contaminants present at the north boundary. The Task 36 technical plan must include a program to evaluate whether the carbon adsorption treatment plant is removing all contaminants from the groundwater to below applicable standards.

Our second concern is that while modifications can be made to improve the effectiveness of the North Boundary Containment System, we believe the current system is functionally flawed due to the collection and recharge system design deficiencies. Therefore, even if the modifications proposed in these comments are incorporated as part of the work plan, Task 36 would still only represent a "band-aid" solution to the problem of preventing the migration of contaminants in groundwater at the north boundary of RMA.

To protect public health and the environment, the collection and treatment of contaminated groundwater at the source areas and at the point of use (private and public drinking water wells) should be implemented as soon as possible. If you have any questions on our comments, please contact Mr. Chris Sutton with this division.

Sincerely,

Chris Sutton fr

Joan W. Sowinski
Acting Director
Hazardous Materials Waste Management Division

JS/CS/ls

xc: Howard Kenison, Deputy Attorney General
Robert Duprey, USEPA Region VIII
Chris Hahn, Shell Oil Company
Brian Anderson, RMA Program Manager Staff Office
Thomas Bick, U.S. Dept. of Justice
Robert Lawrence, USEPA Region VIII
Edward McGrath, Holme, Roberts and Owen

RESPONSES TO
STATE COMMENTS ON TASK 36
DRAFT FINAL TECHNICAL PLAN

General Comments and Responses

Comment 1: Although the Task 36 Draft Technical Plan states that the treatment plant is "effectively removing the organic contaminants from the groundwater," this evaluation is based on data presented in the December 1985 North Boundary Containment/Treatment System (NBCS) Performance Report prepared by the U.S. Waterways Experiment Station (USWES). The USWES Report focused on the treatment plant's effectiveness in treating a limited subset of the contaminants present in the groundwater at the north boundary (i.e., DIMP, DCPD and DBCP). Furthermore, that report indicated that substantial levels of DIMP and DCPD were still present in many of the effluent samples discharged from the treatment plant. Therefore, to be consistent with the requirements of the National Contingency Plan (NCP) and the Superfund Amendments and Reauthorization Act (SARA), the Task 36 Component Response Action Assessment must:

a. Fully evaluate the effectiveness of the carbon adsorption treatment plant. At a minimum, the treatment plant influent and effluent water quality must be sampled on a bimonthly basis during the study period for the complete list of contaminants found in the groundwater at the north boundary, including volatile organics, pesticides, semi-volatile organics, "unknown" or non-target organics and inorganic contaminants: and

b. Demonstrate that the NBCS treatment plant is removing all contaminants to below the applicable and relevant, or appropriate requirements, standards or criteria (ARARs) as defined in Section 121(d) of SARA. For many of the contaminants at the north boundary, the ARARs are

the Maximum Contaminant Level Goals (MCLGs) established by the Safe Drinking Water Act (SDWA). For contaminants where the MCLGs are set at zero, or where Maximum Contaminant Levels (MCLs) or MCLGs have not been proposed or established, the NBCs treatment plant must be operated to at least attain concentration levels of a contaminant that reflect a 10^{-6} Cancer Assessment Group (CAG) cancer risk factor over a 70 year lifetime exposure. If no MCLG, MCL or CAG cancer risk value exists for a particular contaminant in the groundwater, the treatment plant must be operated to at least attain a level or standard that will not exceed the level established for a lifetime exposure for such contaminants in an EPA Office of Drinking Water Health Advisory (HA) or in an EPA Health Effects Assessment (HEA). When Chemical contaminants have an MCLG, CAG 10^{-6} risk, HA or HEA standard below minimum detection limits, and a determination is made that it is technically impracticable from an engineering perspective to meet that standard, the minimum detection limits should be used as the standard for operation of the plant. For chemical contaminants where there are no established or proposed standards as described above, minimum detection limits should be used as the standard for operation of the plant until sufficient toxicological information exists to establish a health based standard.

This complete assessment of the NBCS treatment plant should be conducted as part of Task 36 to ensure that the entire NBCS is operating in compliance with all applicable laws and standards.

Response: A modification to the original scope-of-work has been completed under Task 36 to include an assessment of the

treatment plant at the North Boundary Containment System (NBCS). A Letter Technical Plan, describing the proposed work, will be sent to the Memorandum of Agreement (MOA) parties after internal Army review.

Despite documented deficiencies in the recharge system, the NBCS is withdrawing, treating, and recharging a major portion of the contaminated ground water approaching the north boundary. The purpose of this task is to recommend modifications that will improve system efficiency. We believe that any effort to improve the effectiveness of the existing system is a technically sound and cost-effective approach to preventing the migration of contaminants from the north boundary of RMA.

a. The list of analytes being determined in samples from the influent and effluent at the treatment plant has been expanded under Task 25 to include all Rocky Mountain Arsenal (RMA) target organic compounds. A number of inorganic contaminants, that have been identified near North Boundary at significant concentrations, will be analyzed under Task 36. At present, there are no plans to determine nontarget organic compounds.

b. The recently added treatment plant assessment will compare all treatment plant water quality data with the applicable and relevant or appropriate requirements (ARARs) developed for the offpost and onpost Feasibility Study in accordance with Section 121 (d) of SARA. This evaluation will be utilized to provide additional documentation on the effectiveness of the system.

Comment 2: To meet the stated objective to develop recommendations for integrated operational modifications and/or design changes to

the NBCS, a groundwater model of the containment system should be considered as part of the technical plan. Modeling is an effective method to project the effects of a variety of design and/or operational changes to the NBCS and to identify which measure or combination of measures can be used to optimize the contaminant/collection/recharge system performance. A properly designed and calibrated model will allow a detailed assessment of flow paths and transport mechanisms under the stress imposed by the boundary containment system. In addition, various modifications or improvements to the system can be tested before being implemented in the field. Predictive scenarios, such as long-term operations, extreme high or low water table conditions, and impacts of system shutdowns can be evaluated.

If a model is to be used, it must be designed to evaluate an area extending beyond the complete lateral extent of the present containment system and vertically into the Denver Formation. The model should also incorporate geologic and hydrologic data at least 1/2 mile up and downgradient of the NBCS.

Response: We are in complete agreement about the stated appropriateness of a ground water model. We believe that a ground water model, more than any other tool, will be effective in evaluating modification alternatives that will be considered under this task. At present, we are proceeding with 2-D cross-sectional modeling at the NBCS. The results of this modeling, along with a thorough analysis of data collected during previous hydrogeologic investigations, will provide additional insight into which type of an areal model is appropriate. The primary objective of an areal model is to evaluate measures which can be taken to optimize the collection/recharge system performance. Currently, we are utilizing an areal model calibrated for the NBCS area by Dr.

James Warner at Colorado State University. Working sessions will continue on this subject to keep the MOA parties involved in the modeling efforts.

<u>Comment 3:</u> Section 1.1. The Statement of the Problem section relies upon the December 1985 USWES NBCS Performance Report prepared by Thompson <u>et al</u>. to identify the system's problems, that Task 36 will address. WES identified several other problem areas that are not being, but should be addressed in Task 36, including:

a. The need for a more comprehensive and frequent monitoring program. WES recommended that additional Alluvial and Denver aquifer monitoring wells be constructed up and downgradient from the NBCS and that certain wells be monitored more frequently than quarterly. Furthermore, WES recommended that continuous water level recorders be installed in key wells to support an evaluation of operation alternatives to optimize the NBCS performance;

b. The need to determine whether the Denver aquifer withdrawal wells and/or pumps can be upgraded to intercept Denver aquifer contamination. Seventeen (17) of the 19 withdrawal wells installed in the "shallow" Denver aquifer do not function as constructed. These wells were installed to remove the contaminants migrating through the Denver sand/sandstone units. However, there is an insufficient amount of groundwater flow to the Denver wells to activate the pumps automatically.

c. The need to remediate the inadequate surface water drainage capacity at 96th Avenue and First Creek: and

d. The need to include treatment filters which would remove suspended solids and carbon fines that are contributing to the problem of reduced recharge capacity.

Response: a. Alluvial and Denver wells have been installed under Task 36 along with a substantial number of deep borings upgradient and downgradient of the boundary. Additional sites are being considered for deep borings and/or well installation on both sides of the soil-bentonite (SB) barrier. Since the fall of 1985, alluvial and Denver wells near the NBCS have been monitored quarterly for water quality and water levels by ESE. A number of wells in the area of the NBCS have been monitored on a weekly basis. We believe that the frequency of the present monitoring programs are adequate for the Task 36 Assessment. More frequent monitoring may be justified after system modification have been initiated to help optimize system performance.

b. A major objective of Task 36 is to define the extent and level of contamination within the Denver Formation near the NBCS. Based on this evaluation, conceptual recommendations for containing contamination in the Denver will be outlined. These recommendations will consider the existing Denver dewatering system and whether this system, as presently installed, can be utilized in the overall containment program.

c. It is agreed that this problem may deserve additional study. However, surface water drainage capacity at 96th Avenue and First Creek is not currently being addressed under Task 36.

d. The need to install treatment filters, which would remove suspended solids and carbon fines from the

treatment plant effluent, is being evaluated under the Treatment Plant Assessment. This is being done specifically to help evaluate means of improving the present recharge capacity.

Specific Comments and Responses

Comment 1: p. 1-3 — The description of the NCBS should state that it is only capable of treating organic constituents. Inorganic contaminants intercepted by the NBCS are blended, pass through the treatment system, and are reinjected into the downgradient Alluvial aquifer without treatment.

Response: The description of the NBCS does not state that the treatment plant is capable of treating inorganic contaminants. There should be no misunderstanding on this point because the plant is clearly described as a carbon-adsorption water treatment plant.

Comment 2: p.1-5 — Historically, the Army has assumed that contamination in the Denver aquifer is constrained to the shallow sand/sandstone deposits. The Army has also assumed that any deep contamination will be force to move up-dip (parallel to bedding) and back into the Alluvial aquifer before migrating off-post (May, 1982). However, deep borings into the Denver formation demonstrate that the sand/sandstone deposits in the northern direction near Basin F are not continuous (U.S. Army, 1979). If the sand/sandstone deposits are discontinuous in this direction, few of the deposits would be extensive enough to intercept the alluvium. Permeability testing of shale, claystone, and siltstone deposits has demonstrated that these deposits can be highly permeable. Thus, groundwater flow is not constrained to follow the dip of sand/sandstone deposits. In addition, the extensive vertical distribution of contaminants demonstrates that groundwater flow does not fit the conceptual model proposed

by the Army. The Army does not have sufficient data on hydraulic gradients or anisotropy of hydraulic conductivity to substantiate their assumptions. In fact, the limited data available seem to contradict it. The discussion in the text should be modified to more accurately reflect the actual flow conditions between the alluvium and the Denver formations.

Response: The narrative on page 1-5 focuses on the basic geology at the NBCS at RMA. It is not intended to describe the complex ground water flow conditions between the alluvium and the Denver throughout RMA. Your comment is more appropriately addressed to Task 44 which is a regional program intended to examine many of the questions you have posed.

Comment 3: p. 1-5 The statement that "water bearing zones in the Denver formation are restricted to sandstone lithologies" implies that no significant flow is occurring in the silts and shales of the Denver. May (1980) determined that the permeabilities of fractured silts and shales at the NBCS are comparable to that of the Denver sandstones. The statement in the text should be modified to reflect the actual flow conditions within the Denver.

Response: The statement that "water bearing zones in the Denver Formation are restricted to sandstone lithologies" is not meant to imply that no significant flow is occurring in fractured silts and shales of the Denver Formation. However, due to the localized and discontinuous nature of these fractured materials, they are not considered as water bearing zones and are not considered major units responsible for significant lateral flow in the Denver Formation. It is recognized that the permeabilities of fractured silts and shales can be significantly greater than that of intact silts and shales and can allow some vertical flow.

Comment 4: p. 1-8 — To be consistent with the text following the table of hydraulic conductivities, the range of conductivities for Denver shales and silts shown in the table should be changed to read, "1×10^{-2} to 5", rather than "1×10^{-2} to 2×10^{-2}".

Response: The table on page 1-8 will be modified to provide ranges of hydraulic conductivity for intact shale and silt and fractured shale and silt.

Comment 5: p. 1-8 — References for the results of the aquifer tests near the NBCS including the field slug tests of the fractured shale documented by May, et al. (1980), should be included in the text.

Response: References for the aquifer tests alluded to on page 1-8 will be included.

Comment 6: p. 30-10 — An insufficient number of wells exist to characterize the Denver aquifer upgradient of the NBCS. Only 21 Denver aquifer monitoring wells will be used to attempt to characterize a two square mile region of variable and complex bedrock geology with depth upgradient of the NBCS. In addition, approximately 40% of the existing 21 Denver aquifer monitoring wells have been designated as questionable based on evaluation of construction factors and, therefore, are not planned for long term chemical sampling. The five new monitoring wells planned (p. 3-20) will not add sufficient resolution to the uncertainty in the upgradient Denver Aquifer. Additional Denver aquifer monitoring wells will need to be constructed to achieve the objectives in the plan.

Response: ESE is in agreement that upgradient sites are necessary to assess the potential for contaminants to bypass the boundary system. However, there are several existing upgradient sites which are being used to monitor water levels in the alluvium

and in the Denver aquifers. These existing wells have been utilized along with existing downgradient wells to assess whether the potential for contaminants bypassing the system in specific sandstone units exists. A number of additional alluvial wells have been installed just upgradient and downgradient (approximately 25 ft) of the SB barrier. These wells were installed at regular intervals along the length of the barrier. The data from many of these wells and other existing alluvial wells have been used along with data from the Denver wells to assess three-dimensional flow patterns on the upgradient and downgradient sides of the SB barrier.

Obviously, a greater level of effort is justified for specific Denver aquifers which are found to be contaminated. For these units, cluster sites are warranted on both the upgradient and downgradient sites of the soil-bentonite barrier. Furthermore, additional upgradient wells may be required to help determine points of entry for contamination into a specific sandstone unit. To date, water quality wells are installed in the major 1st and 2nd sand units present along the length of the barrier. Water quality data from these wells will be used to determine where additional upgradient sites are required. A deep boring and completion of a well cluster installation is being undertaken at the present time at Site EP-27. This site is being installed to investigate sand units which have been found to be contaminated near the SB barrier.

There are existing 1st and 2nd sand wells located at the east end of the SB barrier at Sites 24108, 24120, and 24109. These wells are being monitored under Task 25. Site EP-72 is a cluster site which is scheduled to be installed to the west of the NBCS.

Comment 7: p. 3-20

Section 3.1.2. Section 121 (c) of SARA states in pertinent part:

"No Federal, State or local permit shall be required for the portion of any removal or remedial action conducted entirely onpost, . . ."

Since construction of new "off-post" monitoring wells is neither an "action conducted entirely on-post" nor a portion of the remedial action, the "opinion" expressed in the draft technical plan to the effect that drilling permits need not be obtained, is inaccurate. Therefore, drilling permits for new off-post monitoring wells must be obtained. The statements in Section 3.1.2 to the contrary should be deleted.

Response: Although there exist differences in the interpretation of Section 121(c) of the Superfund Amendments and Reauthorization Act of 1986 (SARA), permits for all offpost wells installed under Task 36 have been obtained. This practice assures that the offpost drilling program will remain in substantive compliance with applicable state laws and regulations.

Comment 8: p. 3-22

Figures 3.2-2a through 3.2-3. Construction details and contingencies for installing monitoring wells in shales/claystones of the Denver aquifer that show evidence of fracturing must be included in the technical plan.

Response: Fractured shale is an anisotropic flow media. If a well is to be completed in this type of material, the construction details should be determined at that time on a site specific basis. To predict all possible conditions that could occur at a site in fractured shale, would require considerable speculation at this time. Only a limited amount of geotechnical effort has been expended historically at RMA to

fully characterize the fractured shale. In the event that a well installation in fractured shale is deemed necessary, a Letter Technical Plan with appropriate details will be issued.

Comment 9: p. 3-32

The Alluvial well installation plan states that "the screen will extend throughout the water-bearing unit "and" will be screened five feet above the water table." Using this plan, well screens of over 20 feet may be installed. Well screens of this length are of limited use in that they may integrate a large interval of variable water quality. Therefore, if saturated thicknesses of over 20 feet are encountered in the alluvium, well clusters should be installed. This has been an established Army policy for both on-post and off-post Alluvial well installation.

Response:

No alluvial well has been installed under this task with a screened length exceeding 20 feet (ft). It is not anticipated that any remaining alluvial wells to be installed under the Task 36 will require a screened length exceeding 20 ft.

Comment 10: p. 3-48

Laboratory permeability tests in nonfractured media will give an estimate of vertical permeability, which is indicative of the potential for vertical migration. Vertical migration of contaminants has been confirmed at RMA and therefore the draft technical plan should not underemphasize the importance of vertical flow.

Response:

This comment was not meant to underestimate the importance of vertical flow at RMA.

Comments 11: p. 3-48

Laboratory tests should include a determination of porosity.

Response: Any laboratory permeability tests performed will include determinations of porosity.

Comment 12: p. 3-49 Vertical borings within the barrier will result in cores with orientation such that permeability analysis of the primarily horizontal flow through the barrier cannot be determined. Alternative methods must be employed to characterize the horizontal permeabilities through the barrier.

Response: Laboratory permeability tests are recommended primarily for barrier samples due to problems that have been noted with performing in situ tests (EPA, 1984). The two primary limitations of laboratory tests are described as:

- o Measurements are obtained from tests performed on a disturbed sample; and
- o Hydraulic conductivity is measured in the vertical direction which is not generally the primary direction of ground water flow.

Every effort will be taken to minimize the effects from the first factor. The second factor is less of a concern regarding the barrier because of the substantial component of vertical flow through it. This vertical component of flow is the result of the significant gradients across the barrier. It is also unclear just how the vertical and horizontal hydraulic conductivities vary within constructed soil-bentonite barriers. We believe that this is the most cost-effective method of providing average hydraulic conductivity values for the barrier.

Comment 13: p. 3-50 To adequately perform an evaluation of the barrier system, high density water level monitoring points upgradient, downgradient, and within the NBCS are required. Water level

monitoring frequency should be monthly, at a minimum. Continuous water level recorders should be installed on a representative subset of piezometer.

Response: The evaluation of the SB barrier is substantially enhanced by water-level wells immediately upgradient and downgradient of the barrier. Therefore, ten additional water-level wells have been installed immediately upgradient and downgradient of the barrier to supplement the existing network. These wells are being monitored on a monthly basis throughout the duration of Task 36. Justification for more frequent monitoring can be discussed with you on a well specific basis.

We do not believe installation of wells in the barrier is advisable. These installations would not provide significant additional information and could seriously impair the integrity of the barrier.

Comment 14: p. 4-1 The chemical analysis program must include GC/MS analyses to identify and quantify non-target organic contaminants and to provide confirmation for the list of organic analytes shown in Table 4.0-1.

Response: GC/MS analyses are performed on approximately 10 percent of the total wells sampled in Task 44, the regional monitoring task. A number of these wells are in the vicinity of the NBCS and the findings of these analyses will be incorporated into the Task 36 monitoring program.

Comment 15: p. 4-2 Table 4.0-1. Analytical detection limits should be listed for each analyte.

Response: Analytical detection limits have been added for each analyte in Table 4.0-1.

Comment 16: p. 8-2 | The NBCS was not designed to capture flow in the bedrock and may not be capable of being retrofitted to achieve the stated goal of intercepting all contamination. The evaluation of the NBCS' dewatering capability should specifically address this issue.

Response: The ability of the NBCS to intercept contaminated flows in the Denver will be evaluated in Task 36.

Comment 17: p. 8-3 | As a result of insufficient recharge capacity, the NBCS has been discharging treated water to a surface bog. This practice has altered the flow field across the barrier and reduced the total volume of water ultimately returned to the groundwater system by allowing evaporation. The effect of this surface drainage on the contaminant flow paths in the hydrogeologic system needs to be evaluated as part of Task 36.

Response: We are in agreement that the bog is a significant factor in the hydrogeologic system at the NBCS. All analyses of system operations and modifications to the system will include the present effects of the bog and those projected based on proposed changes to system operations.

Comment 18: p. 8-4 | The assessment of flow by-passing the NBCS should also evaluate the potential flow through the barrier. Dewatering capacity (well spacing) within the limits of the barrier should be sufficient to substantially lower the water table immediately upgradient of the barrier to prevent a significant challenge to the integrity of the soil-bentonite wall.

Response: A top priority of this task is to reduce the northward directed flow gradient present across the soil-bentonite (SB) barrier. The amount of flow through the barrier is directly

proportional to this gradient. This goal can most likely be achieved by additional dewatering and/or recharge at the NBCS. The optimum proportions of system changes to obtain the stated goal are being studied in this task.

Comment 19: p. 8-10 — Collection of water level data to accurately assess vertical gradients should be included in the monitoring program.

Response: Water level data is being collected in alluvial and Denver wells under Task 36 and 25. Many of the new wells being installed under this task are being placed in clusters specifically to assess the potential for the vertical movement of contaminants.

Comment 20: p. 8-10 — The monitoring and testing program planned should provide useful information. However, other analyses should be completed to more rigorously analyze the data. These methods include statistical analyses of single well data variability, time series analyses to determine and quantify trends in contaminant distribution, and statistical comparisons of contaminant data upgradient and downgradient of the containment system.

Response: Statistical analyses are an appropriate supplementary means of delineating contaminant distribution trends and monitoring system performance. These analyses have been historically performed by Army personnel on data from near the NBCS in annual System Performance Reports to help assess the effectiveness of the system. Task 36 will utilize many of the statistical evaluations performed in these reports (particularly the most recent) to assist in evaluation of the same system and formulating recommendations for response actions. To the extent possible, data from new wells will be used to supplement statistical evaluations that have been performed by the Army.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION VIII

999 18th STREET—SUITE 500

DENVER, COLORADO 80202-2405

MAY 15 1987

19 MAY RECD
BSA

REF: 8HWM-SR

Colonel W. N. Quintrell
Deputy Program Manager
AMXRM-EE Department of the Army
U.S. Army Toxic and Hazardous Materials Agency
Building 4585
Aberdeen Proving Ground, MD 21010-5401

Re: Rocky Mountain Arsenal (RMA),
Comments on Technical Plans for
Tasks 25 & 36

Dear Colonel Quintrell:

We are pleased that the Army is investigating options for response actions for the North Boundary System through Task 36. EPA places high priority on this response action as well as several other interim actions which can be undertaken at RMA before completion of the final RI/FS reports.

Task 25 addresses Boundary Systems Monitoring and is related to Task 36. Our staff and consultants have developed the enclosed comments on the two technical plans.

The Region looks forward to the scheduled May 20, 1987 meeting with the MOA parties on the boundary systems. We are pleased to note that arrangements have been made for Dr. Walter Grube of our Hazardous Waste Engineering Research Laboratory to both meet with your staff and attend the MOA parties meeting. We hope that Dr. Grube's experience with barrier systems will prove especially helpful in your efforts to assess the North Boundary System. Our contact on this matter is Mr.Connally Mears at FTS 564-1528.

Sincerely yours,

Robert L. Duprey, Director
Waste Management Division

enclosure

cc: Thomas P. Looby, CDH
Joan Sowinski, CDH
Chris Hahn, Shell Oil Company
R. D. Lundahl, Shell Oil Company
Thomas Bick, Department of Justice
Elliott Laws, Department of Justice
Brian Anderson, RMA-PMO

RESPONSES TO
EPA COMMENTS ON TASK 36
DRAFT FINAL TEHCNICAL PLAN

<u>Comment 1:</u> Hydraulic aspects of the North Boundary Barrier system need to be corrected so that a southward flow potential exists across the barrier system. Evaluation of barrier effectiveness without this reversed gradient will provide results with limited utility, since a key aspect of successful operation of a barrier of this type is maintenance of a gradient from the clean side toward the contaminated side.

<u>Response</u>: A primary objective of Task 36 is to evaluate and recommend means of correcting the present northward directed alluvial ground water gradients at the soil-bentonite (SB) barrier of the North Boundary Containment System (NCBS). This evaluation will investigate modifications to the system that can achieve additional withdrawal and recharge capacity and will lead to a southward flow potential in the alluvium at the SB barrier. Identifying optimum locations for additional withdrawal and/or recharge components, determining design flow rates, and evaluating specific technologies to achieve these is an integral part of this assessment.

<u>Comment 2:</u> An evaluation of all contaminants in the area upgradient of the barrier system and the ability of the existing system to treat these compounds to meet the appropriate standards should be done. This evaluation should include an expansion of the list of analytes in both influent and effluent streams from the system. An evaluation of operating criteria for the system should be conducted to verify that the compounds with the most rapid breakthrough be used to determine when carbon changeout is necessary.

Response: A modification to the initial scope-of-work for Task 36 has been completed that includes an evaluation of the Treatment System at the NBCS. As part of this assessment, all Rocky Mountain Arsenal (RMA) target organic compounds will be analyzed for in the treatment influent and effluent streams. Additionally, inorganic compounds that have been documented at significant concentrations near the NBCS will be included in the sampling and analysis. All contaminants will be evaluated against applicable or relevant and appropriate requirements (ARARs) being developed for the offpost Feasibility Study conducted under Task 39.

As a part of the treatment assessment, an evaluation of operating criteria for the system will be conducted to verify that compounds with the most rapid breakthrough are being used to determine frequency of carbon changeout.

Comment 3: The proposed data collection and analysis program does not adequately address the potential for migration of contaminants in permeable zones within the Denver Formation around or under the barrier system. A greater density of cored borings in the Denver is required to develop a three-dimensional understanding of the distribution of permeable units and to determine if secondary permeability plays a role in transport of contaminants.

Response: There are two factors which must be considered when evaluating the proposed drilling program for Task 36. First, there are a substantial number of existing wells and a considerable amount of information from previous borings that are being utilized to construct geologic cross-sections, describe three-dimensional flow patterns, and evaluate Denver aquifer water quality. A thorough investigation of this data

has been conducted to identify data gaps and specific locations for future borings and wells.

The second factor which must be considered is that the initial round of wells identified in the Draft Final Technical Plan only represents a portion of the planned installations. ESE believes that a flexible approach to borehole and well site location is warranted at the NBCS. To identify a fixed location for all wells and boreholes based upon existing information, without an allowance to incorporate new data being collected during early parts of the study, is not an effective means of conducting this investigation. Therefore, the specific locations of additional boreholes and wells are being identified and sent to Memorandum of Agreement (MOA) parties in the form of Letter Technical Plans. One such Letter Technical Plan, outlining additional drill sites, has been sent to the MOA parties and has been subsequently discussed in a working session. All future drilling will be handled in a similar manner.

Comment 4: The proposed sampling network does not provide adequate coverage on the west side of the north boundary system. The wells drilled as part of Task 25 will not adequately define the potential movement of contaminants in the bedrock formation under and adjacent to the west wing of the slurry wall. The well coverage off-post north of the west side of the barrier is also not adequate to define contaminant movement in both the alluvium and the bedrock. More wells are needed in order to adequately address potential changes in the boundary system. The proposed sites for new monitor wells as part of Task 36 (Figure 3.1-3) do not provide sufficient coverage on the west side.

Response: In addition to the wells identified in Figure 3.1-2 of the Draft Final Technical Plan, several additional sites have been drilled or are being considered for drilling on the west side of the NBCS. These sites are identified in the Draft Final of the Comprehensive Drilling program. Table 1 shows a listing of additional well sites, their locations, the types of sites, their status, and under which task they are being installed.

Comment 5: The proposed well development (Section 3.2.9) procedure should be modified to require use of a surge block in conjunction with the submersible pump or bailer. The well should be surged in between pumping stages until the well can be surged and the water is clear.

Response: The present well development procedures being implemented in the field include surging of the wells. This is accomplished by raising and lowering a submersible pump or bailer repeatedly prior to water withdrawal. The procedure is repeated until the withdrawn water is clear. Utilization of this procedure has yielded satisfactory water quality samples.

Comment 6: In order to evaluate (in a timely manner) the potential for contaminants bypassing the boundary system, this plan should be modified to include the drilling of upgradient cluster wells during the early phase of the program. At least one cluster of wells should be located on each end of the barrier.

Response: ESE is in agreement that upgradient sites are necessary to assess the potential for contaminants to bypass the boundary system. However, there are several existing upgradient wells which are being used to monitor water levels in the alluvium

Table 1. Well Sites, Location, Type, Status and Associated Task

Well Number	Location	Type	Status	Task
E-38	950 ft North of RMA North Boundary Along HWY 2	Deep Corehole Alluvial 1st Sand 2nd Sand	Complete Complete Complete Complete	39
E-72	1,300 ft south of north Section Line and 1,800 ft east of west section line of Section 23	Deep Corehole Alluvial 1st Sand 2nd Sand	Not Drilled Not Drilled Not Drilled	44
EP-71	1,400 ft of south of north section line and 1,050 west of east section line of Section 22	Deep Corehole Alluvial 1st Sand 2nd Sand	Not Drilled Not Drilled	44
EP-19	1,780 ft west of D Street and 210 ft south of 96th Ave in Section 23	Deep Corehole 1st Sand 2nd Sand Alluvial	Complete Not Drilled Not Drilled Not Drilled	36
EP-20	1,100 ft west of D Street and 140 ft south of 96th Ave in Section 23	Deep Corehole 1st Sand 2nd Sand Alluvial	Complete Not Drilled Not Drilled Not Drilled	36
EP-21	650 ft west of D Street and 130 ft south of 96th Ave in Section 23	Deep Corehole 1st Sand 2nd Sand Alluvial	Complete Not Drilled Not Drilled	36

Table 1. Well Sites, Location, Type, Status and Associated Task

Well Number	Location	Type	Status	Task
EP-25	850 ft west of D Street and 900 ft south of 96th Ave in Section 23	Deep Corehole 1st Sand	Not Drilled Not Drilled	36
EP-26	210 ft west of D Street and 950 ft south of 96th Ave in Section 23	Deep Corehole 1st Sand	Not Drilled Not Drilled	36
EP-27	710 ft west of D Street and 1,130 ft south of 96th Ave in Section 23	Deep Corehole 1st Sand	Complete Complete	36
EP-28	2,480 ft west of D Street and 235 ft south of 96th Ave in Section 23	Deep Corehole 1st Sand 2nd Sand	Complete Not Drilled Not Drilled	36

Additional drilling sites are being considered on the west side of the NBCS. Specific locations and horizons for wells will be dependent upon geologic, hydrologic, and water quality data obtained from the sites described above.

and in the Denver aquifers. These existing wells have been utilized along with existing downgradient wells to assess whether the potential exists for contaminants to bypass the system in specific sandstone units. The existing Denver wells used in this preliminary assessment are shown on the enclosed map and are listed in Table 2. Alluvial wells have been installed just (approximately 25 ft) upgradient and downgradient of the soil-bentonite (SB) barrier. These wells were installed at regular intervals along the length of the barrier. The data from many of these wells and other existing alluvial wells are being used along with the Denver wells to assess three-dimensional flow patterns on the upgradient and downgradient sides of the SB barrier.

A greater level of effort is justified for specific Denver aquifers which are found to be contaminated. For these units, cluster sites are warranted on both the upgradient and downgradient sides of the SB barrier. Furthermore, additional upgradient wells may be required to help determine points of entry for contamination into a specific aquifer. To date, water quality wells are installed in the major 1st and 2nd sand units present along the length of the barrier. Water quality data from these wells will be used to determine where additional upgradient sites are required. A deep boring and completion of well cluster installation are being undertaken at the present time at site EP-27. This site is being installed to investigate upgradient sand units which have been found to be contaminated near the SB barrier.

There are existing 1st and 2nd sand wells located just to the east of the SB barrier at Sites 24108, 24120, and 24109. These wells are being monitored under Task 25. Site EP-72 is a cluster site which is scheduled to be installed to the west of the NBCS under Task 44.

Table 2. Denver Wells in the Area of the North Boundary

Well Number	Horizon
24127	NBE#1
24086	
24108	NBE#1
24124	
24109	NBE#2
24120	NBE#2
24135	NBE#1
24136	NBE#2
24159	
24167	NBE#2
24171	NBE#2
24174	NBE#2
37376	NBE#2
24137	NBE#3
24168	NBE#3
24175	NBE#3
23202	NBW#1
23176	NBW#1-1A
23177	NBW#1-1A
23178	Weathered Shale/All
23180	
23189	
23190	
23203	NBW#1-1A
23204	NBW#1
23161	NBW#2
23181	
23200	NBW#2
23209	NBW#2
23201	NBW#3
37318	NBW#3
23210	205'-215'
37319	145'-154'
*23199	
37387	NBW#1
37388	NBW#2
37390	NBE#2
37371	NBW#2
37372	NBW#3

*Water Levels Only.

Comment 7: A downgradient cluster well should be located west of the proposed E-66 site. A potential site is near Well 038.

Response: The area west of E-66 is being covered by Tasks 25 and 44. A cluster site has been proposed to the west of E-66 at EP-72.

Comment 8: The evaluation of the de-watering system should include an analysis of the potential for improving well yield of existing wells by redeveloping the pumping wells. The low yield may be a result of inadequate development when the wells were initially installed. A number of randomly selected wells should be extensively redeveloped using a surge block and pumping combination to determine if well yields can be increased to levels above those at the time of original installation.

Response: All dewatering wells are cleaned and redeveloped on an annual basis. The procedure includes extensive surging, jetting, and pumping.

Comment 9: The evaluation of the de-watering and recharge system should include some modeling to assist in evaluating the impact of new wells. The evaluation should look at the affect of a new line of withdrawal wells in the center of the main plume. These wells should be a sufficient distance upgradient of the barrier to minimize the contact of highly contaminated water with the barrier. The evaluation should also assess the impact of bedrock injection wells located on both ends of the barrier.

Response: Although it is recognized that the recharge system is not adequate to achieve the desired hydraulic conditions at the SB barrier, it is not clear to what extent the operation of

the dewatering system limits system effectiveness. ESE believes that the dewatering system can most effectively be evaluated by a numerical ground water model. The primary objectives for such a model would be to assess the adequacy of the present dewatering system and to help optimize placement of additional recharge units. We believe that modeling should be performed to define needed modifications to the dewatering system before individual wells are tested or additional dewatering wells installed.

Currently, we are utilizing a model calibrated for the NBCS area by Dr. James Warner at Colorado State University to simulate different withdrawal and recharge scenarios. Efforts are being made, to the fullest extent possible, to setup additional working sessions with the MOA parties to discuss modeling efforts.

<u>Comment 10:</u> Section 8.23.2 should be modified to call for slug tests to be run in <u>all</u> new monitor wells.

<u>Response:</u> A considerable number of aquifer tests have been conducted in the vicinity of the NBCS. These tests include both pumping and slug varieties. We believe that pumping tests in the alluvium are the best method of determining average aquifer properties over a large area. We have compiled and analyzed previous alluvial aquifer tests near the NBCS. These results are available upon request. Additional slug tests in the alluvium would not add significantly to the present estimates of transmissivity and would not provide any sufficient data on storage properties of the alluvial aquifer.

A considerable number of slug tests were performed by Waterways Experiment Station (WES) on Denver sandstone units near the NBCS in 1979. ESE has compiled and analyzed this

data. We believe that these tests provide representative hydraulic conductivity data for the majority of sandstone units within the upper 100 ft of stratum near the NBCS. This data has been used to estimate flow rates in the Denver near the NBCS.

There are currently two specific sandstone units near the NBCS which have shown contamination and for which past aquifer tests are considered suspect. We believe that additional slug tests on these two units are appropriate to more accurately determine the quantity of water flowing in these units and assess to what extent they contribute to offpost alluvial ground water flow.

Comment 11: The proposed completion for wells in the 1st and 2nd Denver Sands calls for screening the entire sand section. Depending on the thickness of these sands, screen intervals could be greater than five feet. Screen intervals greater than five feet may integrate the water quality in the zone and mask variations in the water quality which may exist. A larger screen interval will also make it difficult to assess vertical flow gradients in the vicinity of the barrier. The completion protocol should specify screens no greater than five feet. If the sands are thicker, a second well should be constructed.

Response: In general, sandstone units at the NBCS are thin relative to units elsewhere at RMA. We believe that it is inappropriate to install multiple screens in these units for two primary reasons. First, vertical gradients can be more effectively determined by monitoring intersand water-levels. Second, remediations of contaminated Denver sandstone water could not account for stratification and would have to address the entire unit. We believe that installing wells in additional

sandstone units is a more appropriate utilization of resources.

Comment 12: At each of the well clusters a well should be completed in the shale or siltstone at the top of the bedrock contact to access the potential movement through fractures in the shale. These wells should be constructed through the alluvium in the same manner as wells drilled to the Denver Sands in order to prevent cross contamination. Slug tests should also be conducted on these wells.

Response: It is recognized that fractured shale may be acting as a contaminant transport mechanism near the bedrock contact with the alluvium in areas near the NBCS. However, we do not believe that installation of wells in isolated areas, along with the performance of slug tests, will provide definitive data concerning the overall extent to which fractured shale conducts water. Previous tests performed in fractured shale near the NBCS have shown hydraulic conductivity values which vary by more than two orders of magnitude. This difference probably reflects true variation in the field. Therefore, to extrapolate isolated horizontal hydraulic conductivity measurements over a considerable area would not be representative of actual field conditions.

Another factor which must be considered is that even with proper well installation techniques, the placement of wells in areas where the shale layer is relatively thin may lead to a greater probability of cross-contamination between the alluvium and underlying Denver aquifers. We do not believe that these wells are justified given the additional cross-contamination risk and the considerable expense involved and the fact that it will not be fundamental to eventual remediation.

Comment 13: A program to winterize the dewatering and reinjection system should be implemented to avoid the winter shutdown problems.

Response: Winterization of the dewatering and recharge system is not being investigated under the present scope-of-work in this task.

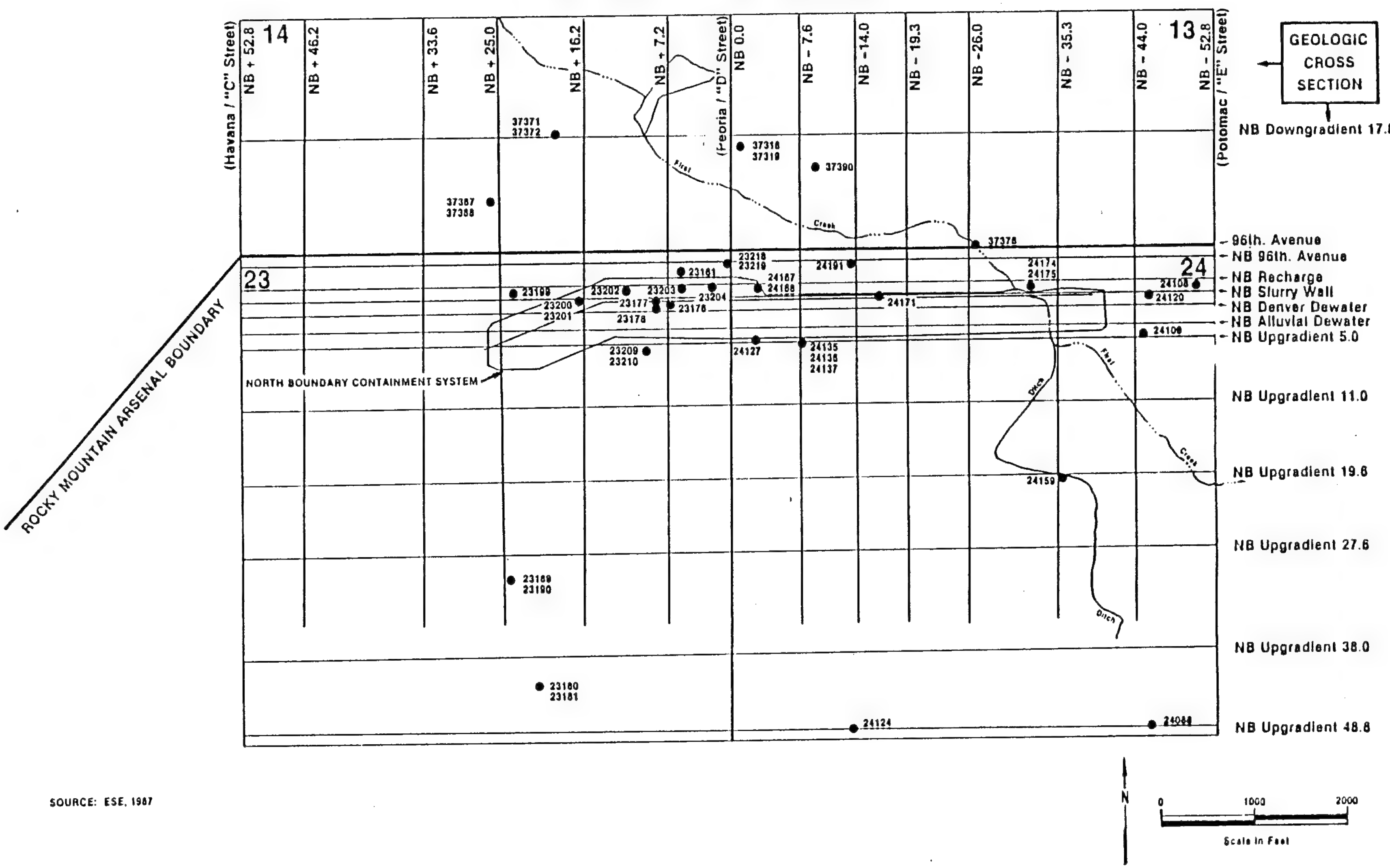
Comment 14: The Task 36 evaluation should assess the feasibility of increasing injection pressure at existing recharge wells.

Response: The Task 36 evaluation will assess the feasibility of increasing injection pressure at existing recharge wells.

Comment 15: The feasibility of using new injection wells in alluvium west of the North Boundary system should be assessed.

Response: The feasibility of using new recharge wells in the alluvium on the western side of the NBCS is being evaluated.

DENVER WELLS IN THE AREA OF THE NORTH BOUNDARY



SOURCE: ESE, 1987

FMS9

Shell Oil Company

One Shell Plaza
P.O. Box 4320
Houston Texas 77210

04 MAY RECD

April 22, 1987

USATHAMA
Office of the Program Manager
Rocky Mountain Arsenal Contamination Cleanup
ATTN: AMXRM-PM: Col. Wallace N. Quintrell (Deputy)
Bldg E4585, Trailer
Aberdeen Proving Ground, MD 21010-5401

Dear Colonel Quintrell:

Enclosed herewith are Shell Oil's comments on the Task Number 36 Draft Final Technical Plan, North Boundary System Component Response Action Assessment.

The broad objective of Task 36 is to develop recommendations for operational and design changes to the North Boundary Containment System (NBCS) to correct actual and potential performance deficiencies. The plan proposes to accomplish this through a broad range of geological, hydrological, water quality, operational, construction, performance, design, etc. studies, culminating in an assessment of overall system integrity. This approach is taken notwithstanding acknowledgment in the Plan that the dewatering/recharge system is periodically incapable of handling necessary groundwater flow rates and that this, "more than any other factor...has led to increased potential for flow of groundwater through and around the control system".

Shell recommends that the plan be modified to place top priority on establishing on a sustained basis adequate dewatering and recharge capacities and the intended hydraulic gradient across the barrier. The December 1985 NBCS Performance Report, Thompson, et. al., should provide a sufficient basis for identifying corrective actions required, most of which seem amenable to early implementation. By assigning top priority to this performance aspect, the full potential of the existing system to intercept contaminated groundwater will be realized at the earliest possible time. Plan elements which collect data sensitive to inadequate dewatering/recharge flows and the barrier hydraulic gradient should be deferred until these inadequacies are corrected. Otherwise, the data would only confirm these known deficiencies.

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Second highest priority should be assigned to investigation of groundwater flows at the alluvial-Denver Formation interface and within the Denver Formation. However, as discussed in the attached comments, the construction of existing and new wells and the well density proposed in the Plan are inadequate for accomplishment of this objective.

Very truly yours,

R. W. Trumbull

for C. K. Hahn
Manager
Denver Site Project

RDL:ajg

Attachment

cc: (w/attachment)
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3

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RESPONSES TO SHELL COMMENTS ON TASK 36 TECHNICAL PLAN

General Comments:

There are two serious problems with this Technical Plan. First, although operating experience and field data clearly indicate that inadequate dewatering and recharge rates chronically impair performance of the NBCS, no special urgency or priority is assigned to resolving these deficiencies. As a result, actual or potential system by-passing will continue through this investigation and data, particularly hydrologic data, collected during the investigation will only reflect a hydraulically malfunctioning system. Second, the Plan is not extensive enough to fulfill all its stated objectives, particularly when considering the geologic complexity at this site and the size of the NBCS.

As noted at page 8-1 of this Technical Plan, the inability of the NBCS to handle required flow rates at certain times has, more than any other factor, led to increased potential for flow of groundwater through and around it. To remedy this situation, recharge volume should be increased by installing more injection wells (or trenches) and/or increasing recharge rates to existing wells. Improved stream factors on the pumping systems will also be required. These should be done at the earliest possible time and before conducting geological or hydrological studies whose data are sensitive to NBCS operations. After the direction of the hydraulic gradient is reversed, even if there are windows, pipings and other structural problems of the slurry wall, only treated water would flow from north to south across or around the slurry wall. The next action should be to better define the vertical flow component at the interface of the alluvial aquifer and the Denver Formation and in the Denver Formation itself. However, as discussed below, the number of wells currently planned is vastly insufficient to define vertical flows.

A stated objective (page 8-6) of this plan is to prepare a three dimensional analysis of the capability of the bedrock to conduct or impede groundwater flow. To define the three-dimensional transport system of this highly heterogeneous and an isotropic system will require a very dense three-dimensional well network. Even with the inclusion of the Tasks 36 wells, the total number of wells are not sufficient to define the three-dimensional flow field, particularly the vertical component. Flow in the Denver Formation is generally along bedding planes or within sands and is principally horizontal. Hydraulic head differences between the Denver Formation and alluvium or between different layers within the Denver Formation do not necessarily imply that vertical flow is occurring even though the potential exists. To accomplish the three-dimensional objective, a much more detailed technical plan is required.

Because of the length and depth of the slurry wall, it is very doubtful that isolated sampling ("five to ten sampling locations") of the barrier materials will provide any conclusive or comprehensive information.

General Responses:

ESE has assigned top priority to the assessment of the dewatering and recharge system at the North Boundary Containment System (NBCS). However, we believe that to install additional recharge and dewatering capacity without having specific design goals and without knowing the causes of poor efficiency in the existing installation could result in less than adequate modifications. For long-term modifications to the system. specific design objectives are essential.

The Army has initiated an interim response study to examine a more immediate solution to the historically poor recharge capacity on the west side of the NBCS. This will involve the

installation of additional recharge units west of "D" Street. The long-term solution to the problem will be addressed in Task 36 and supplement any short-term actions now being considered.

In order to identify specific design goals, an analysis of the dewatering and recharge system is required. The most efficient means of analysis is a numerical ground water model. The primary objectives of such a model are to assess the adequacy of present withdrawal and recharge rates and locations and evaluate the effects of different proposed modifications to these systems. We believe that implementation of such a tool is an essential first step before actual field installation can begin. Working sessions are currently underway with the Memorandum of Agreement (MOA) parties to discuss the most appropriate type of model to achieve the stated goals. Currently, we are utilizing a model calibrated for the NBCS area by Dr. James Warner at Colorado State University to simulate different withdrawal and recharge scenarios.

There are two factors which must be considered when evaluating the proposed drilling program for Task 36. First there are a substantial number of existing wells and a considerable amount of information from previous borings that are being utilized to construct geologic cross-sections, describe three-dimensional flow patterns, and evaluate Denver aquifer water quality. A thorough investigation of this data has been conducted to identify data gaps and specific locations for future borings and wells.

The second factor which must be considered is that the initial round of wells identified in the Draft Final only represents a portion of the planned installations. ESE believes that a flexible approach to borehole and well site location is warranted at the NBCS. To identify a fixed location for all wells and boreholes based upon existing information, without an

allowance to incorporate new data being collected during early parts of the study, is not an efficient means of conducting this investigation. Therefore the specific locations of additional boreholes and wells are being identified and sent to MOA parties in the form of Letter Technical Plans. One such Letter Technical Plan, outlining additional drill sites, has been sent to the MOA parties and has been subsequently discussed in a working session. All future drilling will be handled in a similar manner.

A Letter Technical Plan was included in the Draft Final Technical Plan that outlined a preliminary evaluation of the construction of both portions of the barrier. The conclusions of this review are summarized below:

- The construction procedures used for both portions of the barrier were considered adequate to prevent the occurrence of large permeable zones within them;
- Even if a few relatively permeable zones do exist within the barrier, a substantial number (possibly 100 or more) of sampling locations would be required to detect them. If some more permeable zones are located, it is reasoned that correcting the hydraulics of the system would render this an insignificant fact;
- To document the hydraulic conductivity of the barrier and to assess what deviations from the design hydraulic conductivity may have occurred, a few isolated sampling locations were proposed.

The objectives of the sampling is to primarily document average hydraulic properties of the soil-bentonite (SB) barrier. This data will be extremely useful in calibrating a model to analyze system operations and to estimate flow rates through the barrier.

Specific Comments and Responses

Comment 1: Page 1-1, second paragraph	Disposal practices took place over a period of 40 years.
Response:	This comment has been noted and the text in the Technical Plan corrected.
Comment 2: Page 1-5, first paragraph	Sediments are Holocene to Pleistocene.
Response:	We agree with this comment. Alluvial sediments are of Holocene to Pleistocene Age. The text in the Technical Plan has been corrected.
Comment 3: Page 1-5, second paragraph	The Denver Formation thickness at the NBCS is approximately 170 feet thick. Shell is not aware of any record of "lignite beds and carbonaceous shale" along the NBCS. Lignite beds and carbonaceous shale are common along the mid-central part of the RMA east of the NBCS.
Response:	The range of thicknesses of the Denver Formation at RMA was approximated at 210 to 370 feet (ft). Based upon an evaluation of the geology at the NBCS we believe the top of the Arapahoe is somewhat greater than 200 ft deep. Lignitic shale and thin lignite beds have been documented in several boring logs near the NBCS. However, the thickness of this material is generally less than that of the lignite beds in the Basin A area of RMA and individual units are not nearly as continuous.

Comment 4: Page 1-8, table	Please provide reference(s) for source(s) of these data.
Response:	A reference will be added to the Technical Plan to document the source of the values given.
Comment 5: Page 1-10, first full paragraph	As-built drawings show that the west end of the pilot wall is anchored in a Denver Sand.
Response:	The first full paragraph on Page 1-10 states that "the barrier is anchored in the Denver Formation." Whether the barrier is anchored in Denver Shale or in Denver sand, does not make this statement incorrect.
Comment 6: Page 1-10, third full paragraph	For Manifold A, eleven Denver wells are indicated, but only 8 are listed, Wells 336 through 343. Wells 344, 345, and 346 are not assigned to any manifold. We believe the flow from these wells is handled by Manifold A. The drawing for the manifold alignment and system configuration shows these wells in the area of Manifold B, but no Denver Wells are indicated in Manifold B.
Response:	Denver dewatering Wells 344, 345, and 346 are assigned to Manifold A. Wells 347 through 354 are connected to the C Manifold.
Comment 7: Page 1-12, second full paragraph	It would be useful to include in this paragraph a statement on the estimated volume of water approaching the NECS. The Thompson, et. al., (1985) report (page 8) states that this volume appears to be in the 250-325 gpm range.
Response:	Based upon our preliminary review of aquifer tests, previous modeling efforts system operations data and the hydrogeology

near the NBCS, we believe that the flow rate range quoted by the Thompson, et. al. (1985) report is the most accurate to date. Our best estimate at this time would quote essentially the same range.

Comment 8: Page 1-24, fourth bullet

The operating goals for recharge capability, as well as for recharge capability, as well as for dewatering and treatment capacity, should be based on the volume of groundwater required to be intercepted for positive control of the groundwater regime

Response:

We are in total agreement with this statement. The utilization of a ground water model or models will be an effective means of improving our preliminary estimates of the flows that must be intercepted for positive control of the ground water regime.

Comment 9: Page 1-14, fourth bullet

This objective should include an investigation of the mesh size of the carbon used in the adsorbers to optimize adsorber performance and minimize generation of carbon fines for removal in downstream filter systems.

Response:

As part of the recently added treatment assessment component of this task, we plan to examine the mesh size of the carbon used in the absorbers. The primary focus of this examination will be to determine if the present mesh size being used is optimum for absorber performance and to minimize generation of carbon fines.

Comment 10: Page 2-1

Analysis of the dewatering/recharge system should be elevated to top priority in the first phase. Data which is sensitive to the performance of the dewatering/recharge systems should not be collected until satisfactory performance of this system is achieved.

Response:

Although the analysis of the dewatering/recharge system is listed last in the first paragraph of this page, this does not imply that less importance is attached to this component. In

fact, we believe we have assigned the highest priority to this component of the study.

Comment 11: Table 3.1-1	On the Task 25 well list, 187 wells of 238 total are classified as either Unacceptable or Questionable. On the Task 4 list, 5 of 24 wells are so classified. Wells in the Unacceptable category should not be used for water quality measurements.
Response:	This comment will be addressed in the Task 25 and Task 44 responses.
Comment 12: Page 3-1, 3.1 Subsurface Investigation Program	A time schedule covering the elements of the program should be included.
Response:	We do not believe that the Technical Plan is an appropriate place for inclusion of a time schedule. However, a time schedule can be provided to interested parties upon request.
Comment 13: Page 3-11, 3.1.1.1 Barrier Investigation	Five to 10 sample locations are insufficient to provide conclusive results.
Response:	The response to this comment is included as the final response in the general comments section.
Comment 14: Tables 3.1-3 and 3.1-2	More monitoring wells are necessary along the north paleochannel in the SE/4 of Section 13.

Response: Existing offpost data indicates that a large portion of the alluvium in the southeast quarter of Section 13 is unsaturated. However, towards the midline of Section 13 the saturated alluvium tends to broaden to the east. A number of alluvial wells and/or boreholes have been proposed under Task 39 along the midline of Section 13.

Comment 15: Page 3-35, 3.4 Abandonment
Instructions, particularly those regarding the relationship between grouting and removal of casing, are not very clear.

Response: The procedure for placing grout and removing casing in increments has been reworded to make this method clearer.

Comment 16: Page 3-36, first paragraph
The requirement for all field personnel to maintain a written record of their daily activities is excessive. This requirement should be limited, e.g., to only personnel in charge or supervision from either the contractor, driller or engineer.

Response: The requirements for record keeping by field personnel was incorrectly stated in the Technical Plan. The Drill Site Geologist maintains a record of daily activities for all other field personnel at a site. All field personnel are noted on this record and it is signed each day by the Drill Site Geologist. This record is not kept individually by each field member. The text in the Technical Plan has been corrected to reflect this fact.

Comment 17: Page 3-48, fourth paragraph
If data from laboratory permeability testing is so unreliable, why do the tests?

Response: Laboratory permeability tests are recommended primarily for barrier samples due to problems that have been noted with trying

to perform in situ tests (EPA, 1984). The two primary limitations of laboratory tests are described as:

- o Measurements are obtained from tests performed on a disturbed sample; and
- o Hydraulic conductivity is measured in the vertical direction which is not generally the primary direction of ground water flow.

Every effort will be taken to minimize the effects from the first factor. The second factor is less of a concern with regards to the barrier because of the significant component of vertical flow through it. This vertical component of flow is the result of the gradients across the barrier. It is also unclear just how the vertical and horizontal hydraulic conductivities vary within constructed soil-bentonite barriers. We believe that the method stated is the most cost-effective method of providing average hydraulic conductivity values for the barrier.

Comment 18: Page 3-48, fifth paragraph	How will vertical gradients be obtained? Existing monitoring wells are inadequate for this purpose and it is not indicated that proposed new wells will be constructed in clusters of descending wells to obtain vertical gradients.
Response:	Many of our proposed installations are either being completed as cluster sites or coupled with existing wells to provide vertical gradient information. At all locations where Denver wells are installed, deep borings are drilled to evaluate the geology. A primary purpose of these deep borings is to allow for the efficient installation of additional descending wells if deemed necessary.
Comment 19: Page 3-49, second paragraph	The procedure for carrying out fracture analyses is not described.

Response: The specific procedure for carrying out any fracture analysis that is deemed appropriate, has not been decided upon.

Comment 20: Page 4-3, Table 4.0-1

Why is EPA Method 622, a quantitative method for phosphorus containing compounds in water, listed as quantitative for DIMP/DMMP?

Mercury, cadmium, chronium and zinc have been detected above indicator levels in wells located in the north sector of Section 36 (e.g. Well 26041). These analytes should be included in the list of organics for analyses.

Response: EPA Method 611 is a quantitative method for phosphorus containing compounds in water. This correction has been made to the Technical Plan.

It is not clear in the comments which section of RMA is referred to when discussing mercury, cadmium, chromium, and zinc detections. Are you referring to Section 36 or Section 26 since Well 26041 (from Section 26) is used as an example. These analyses are inorganic elements, not organics as stated in the comments.

Comment 21: Page 8-1, 8.0 System Assessment/ Remedial Action

As discussed in General Comments, highest priority should be placed on providing on a sustained basis an adequate dewatering/ recharge capacity. This can be done quickly by simply adding more wells (or trenches) with optimization of wells in the two systems to be done at a later date, if necessary. Improvement of stream factors will also be required. Assessment of "the flow of groundwater that is by-passing the system" should not commence until adequate dewatering/recharge capability and the desired hydraulic gradient across the barrier have been achieved. Would it be possible for Shell to attend the progress/status meetings? Shell believes that we can contribute to the solution of various problems.

Response: This is a very valid point. Assessments of "flow bypassing the system" will have to continue once the desired hydraulic gradient at the barrier is achieved. Changes in alluvial water levels necessary to achieve the desired objective may affect hydrologic conclusions made during the study. However, there are some significant factors to consider with regards to this comment:

- o The Army is in the process of examining an interim recharge system modification;
- o All water quality monitoring wells installed under this task can be utilized for future hydrologic and water quality monitoring;
- o Although changing water levels in the alluvium will have an effect on Denver aquifers in the area of the NBCS, many of the overall flow trends will not be significantly altered.
- o Assessment of the present ground water quality of Denver aquifers should not be delayed while recharge and dewatering modifications are being considered.

ESE believes that this comment has significant technical merit. However, we believe that assessment of contamination bypassing the system (primarily in the Denver) should proceed.

Comment 22:
Page 8-4
8.2.1.1
Geologic
Investigations

A substantially greater number of borings than indicated in this plan will be required to "compile detailed geologic cross sections and maps showing the configuration of alluvial and Denver Formation lithologies".

Response: To date, twelve deep borings have been drilled near the NBCS in conjunction with Task 36. In addition, several borings have been drilled under Task 39 downgradient of the system. Additional boring sites are being considered to address specific data gaps. We are available to discuss geologic cross-sections and address any specific area where additional borings are considered appropriate.

BIBLIOGRAPHY

EPA. 1984. Slurry Trench Construction for Pollution Migration Control. Prepared by JRB Associates Inc. Publication No. EPA-540/2-84-001.